2001 Volcanic Activity in Alaska and Kamchatka: Summary of Events and Response of the Alaska Volcano Observatory

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Open-File Report 2004-1453

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U.S. Geological Survey

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By Robert G. McGimsey[1] and Christina A. Neal[1], and Olga Girina[2]

[1]Alaska Volcano Observatory, 4200 University Dr., Anchorage, AK 99508-4664

[2]Kamchatka Volcanic Eruptions Response Team, Institute of Volcanic Geology and Geochemistry, Piip Blvd. 9 Petropavlovsk-Kamchatsky, 683006, Russia

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

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COVER PHOTO: Mt. Cleveland volcano, on Cleveland Island, one of the Islands of Four Mountains group, erupted February 19, March 11, and March 19, 2001. Copyright photograph courtesy of AeroMap U.S.

INTRODUCTION

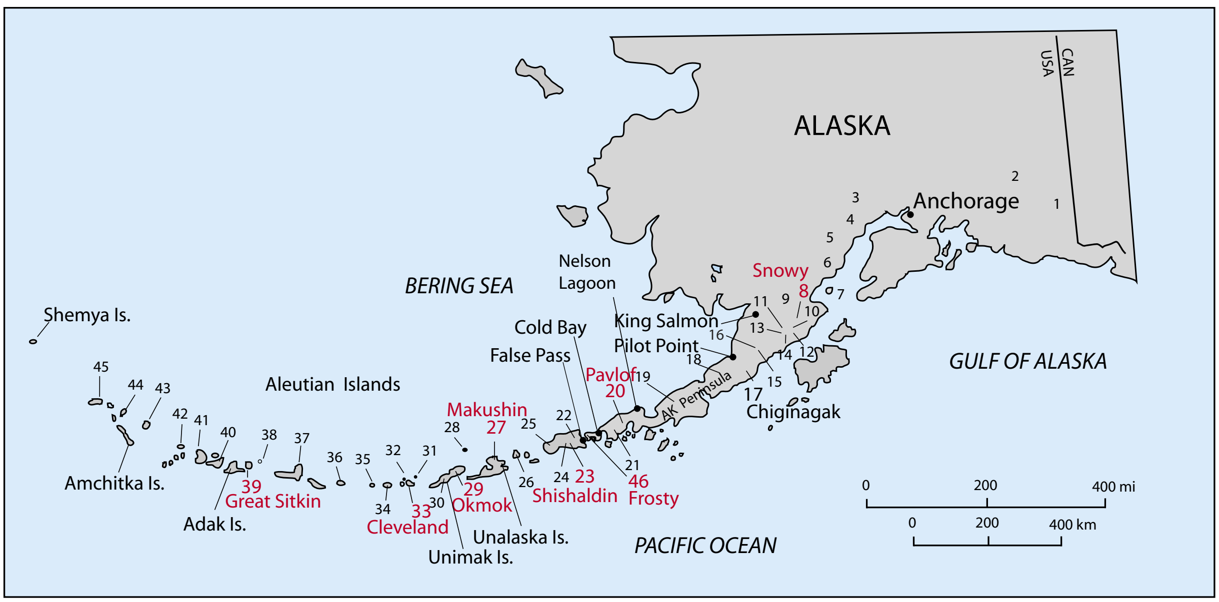
The Alaska Volcano Observatory (AVO) monitors the more than 40 historically active volcanoes of the Aleutian Arc. Of these, 22 are monitored with short-period seismic instrument networks as of the end of 2001 (fig. 1 a,b). The AVO core monitoring program also includes daily analysis of satellite imagery, observation overflights, compilation of pilot reports and reports from local residents and mariners. In 2001, AVO responded to eruptive activity or suspected volcanic activity at or near 8 volcanic centers (fig. 1 a,b; tables 1, 2); Snowy and Kukak of the Kamai Group, Pavlof, Frosty, Shishaldin, Makushin, Okmok, Cleveland, and Great Sitkin volcanoes.

In addition to responding to eruptive activity at Alaskan volcanoes, AVO assisted in the dissemination of information for the Kamchatka Volcanic Eruption Response Team (KVERT) regarding the 2001 activity of 5 Russian volcanoes—Sheveluch, Klyuchevskoy, Bezymianny, Karymsky, and Avachinsky volcanoes (fig. 21; table 3). Due to prevailing wind directions, erupting Kamchatkan and Alaskan volcanoes pose a serious threat to aircraft in the North Pacific (fig. 3).

This report summarizes volcanic activity and AVO responses during 2001, as well as information on the reported activity at Russian volcanoes. Only those reports or inquiries that resulted in a “significant” investment of staff time and energy (here defined as several hours or more for reaction, tracking, and follow-up) are included. AVO typically receives dozens of reports throughout the year of steaming, unusual cloud sightings, or eruption rumors. Most of these are resolved quickly and are not tabulated here as part of the 2001 response record. On rare occasions, AVO issues an information release to dispel rumors of volcanic activity; an example of this occurred on September 7, 2001 when rumors of eruptive activity at historically dormant Frosty volcano—located near Cold Bay, Alaska—were subsequently determined to be false. The phrase “suspect volcanic activity” (SVA), used to characterize several responses, is an eruption report or report of unusual activity that is subsequently determined to be normal or enhanced fumarolic activity, weather-related phenomena, or a non-volcanic event.

The Catalog of Active Volcanoes of the World (CAVW) numbers are provided for referencing the Smithsonian Institute files (Simkin and Siebert, 1994). Descriptions of volcanic activity and AVO responses are presented in geographical order from northeast to southwest along the Aleutian volcanic arc. All elevations reported are above sea level (ASL) unless noted, and time is reported as Alaska Standard Time (AST), Alaska Daylight Time (ADT), or Kamchatka Standard Time (KST), Kamchatka Daylight Time (KDT) (see glossary). We have chosen to preserve English units of measurements when used in primary observations of distance or elevation such as those commonly received via pilot reports and aviation authorities in the United States. A summary of volcanic activity is presented in Table 1. SVA that required significant responses are summarized in Table 2. Table 3 summarizes volcanic activity and responses in Kamchatka. Information on 2001 responses is compiled from AVO weekly updates and information releases, internal bimonthly reports, the AVO 2001 “Chron book”—a chronological collection of daily or weekly staff notes for a particular year—and the Smithsonian Institution Global Volcanism Network Bulletin (GVN), which uses AVO as the source for reports on Alaska volcanoes.

AVO's response to reported remote volcanic activity varies depending on the source and content of the observation. After receiving a report and possibly conducting a follow-up investigation of the factual information, AVO usually contacts the National Weather Service (NWS) and Federal Aviation Administration (FAA) or local residents for corroboration and/or formal notification. For a verified significant eruption or unrest, an established call-down procedure is initiated to formally notify other government agencies, air carriers, facilities at risk, and the media. This information is also disseminated via electronic mail and facsimile. If an eruption or unrest is no longer suspected, a notation is made in AVO files, which are posted on the web, electronically mailed and faxed, and no further action is taken. A special information release may be distributed if eruptive activity is confirmed, and the events are further summarized in the AVO weekly update distributed each Friday via electronic mail and facsimile.



1. *Bona-Churchill*
2. Wrangell
3. *Hayes*
4. Spurr
5. Redoubt
6. Iliamna
7. Augustine
8. *Snowy*
9. *Griggs*
10. Katmai
11. Novarupta
12. Trident
13. Mageik
14. Martin
15. Peulik
16. Ukinrek
17. Chiginagak
18. Aniakchak
19. Veniaminof
20. Pavlof
21. Dutton
22. Isanotski
23. Shishaldin
24. Fisher
25. Westdahl
26. Akutan
27. Makushin
28. Bogosloff
29. Okmok
30. Vsevidof
31. Kagamil
32. Carlisle
33. Cleveland
34. Yunaska
35. Amukta
36. Seguam
37. Korovin
38. Kasatochi
39. Great Sitkin
40. Kanaga
41. Tanaga
42. Gareloi
43. Semisopochnoi
44. Little Sitkin
45. Kiska
46. Frosty*

Figure 1. Location of historically active volcanoes in Alaska and place names used in this summary. Volcanoes mentioned in this report are in bold red. Volcanoes with no documented historical unrest but currently considered hazardous based on late-Holocene eruptive activity are italicized. *Mid-Late Pleistocene in age.

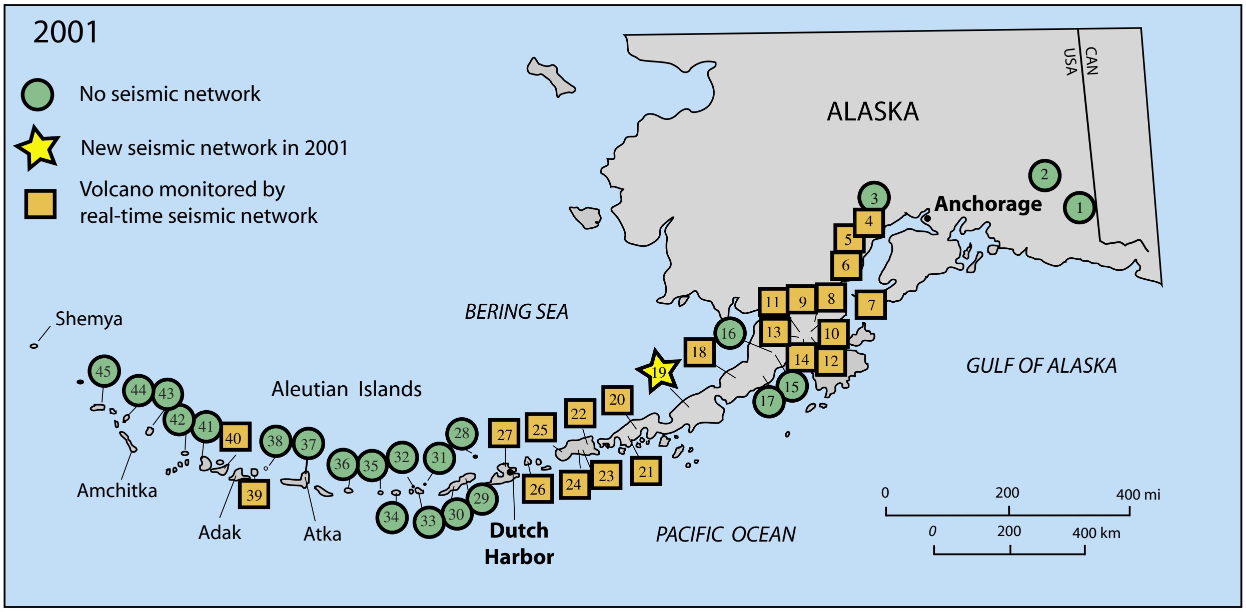


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Figure 2. Map showing those volcanoes monititored with a seismic network as of the end of 2001. Volcanoes with no documented historical unrest but currently hazardous based on late-Holocene eruptive activity are italicized. Volcanoes mentioned in this report shown in bold red. *Mid-Late Pleistocene in age

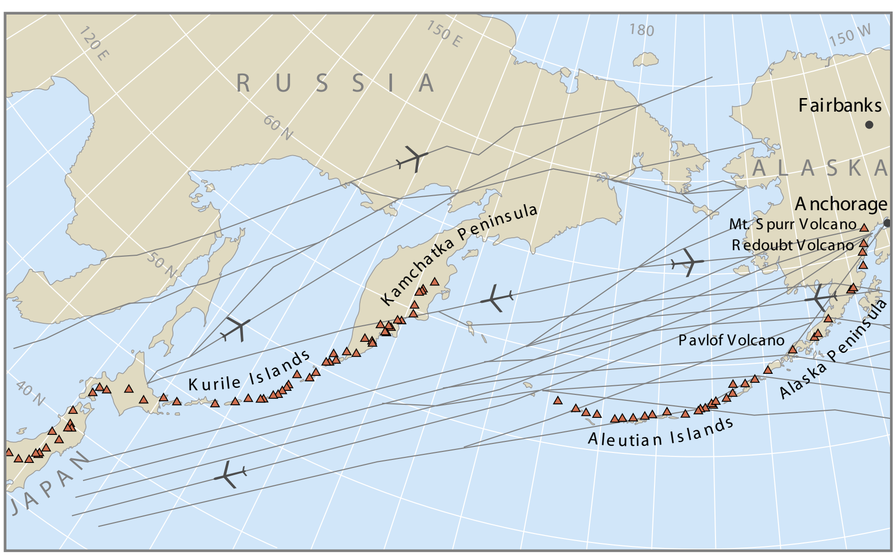


Figure 3. Location of Kamchatkan and Alaska volcanoes and their proximity to North Pacific and Russian Far East air routes.

VOLCANIC ACTIVITY IN ALASKA

NORTHEAST TO SOUTHWEST ALONG ALEUTIAN ARC

KATMAI GROUP
CAVW #1102-20
Snowy
58° 20' N 154° 44' W
7,090 ft (2,161 m)

Kukak
CAVW #1102-23
58° 28' N 154° 21' W
6,693 ft (2,040 m)

SUSPECT VOLCANIC ACTIVITY (SVA)
Pilot reports of steaming hole in glacier on Snowy; steaming vents on Kukak. [Note: For the purposes of this report, the Katmai Group includes: Kukak, Snowy, Katmai, Trident, Novarupta, Mageik, and Martin volcanoes (all closely situated within Katmai National Park and Preserve on the Alaska Peninsula.)]

On June 27, 2001, Willie Hall of Kodiak Air Service called to report his observations of the "steaming hole" in the glacier midway down the south flank of Snowy Mountain. Mr. Hall was the source for the first observations of the steaming hole in September, 2000 (Neal and others, 2004) (figs. 4 and 5). Hall reported that he flew over the area in late May/early June, 2001 using the coordinates previously established and could find no evidence of the hole. Keith Echelmeyer (UAF/GI glaciologist) conducted airborne glacier surveying in the Katmai region in early May and he, too, used the coordinates to examine the area where the hole was reported. He observed that the hole was still there, but "not a big deal…. not steaming and mostly snow-filled" (fig. 6).

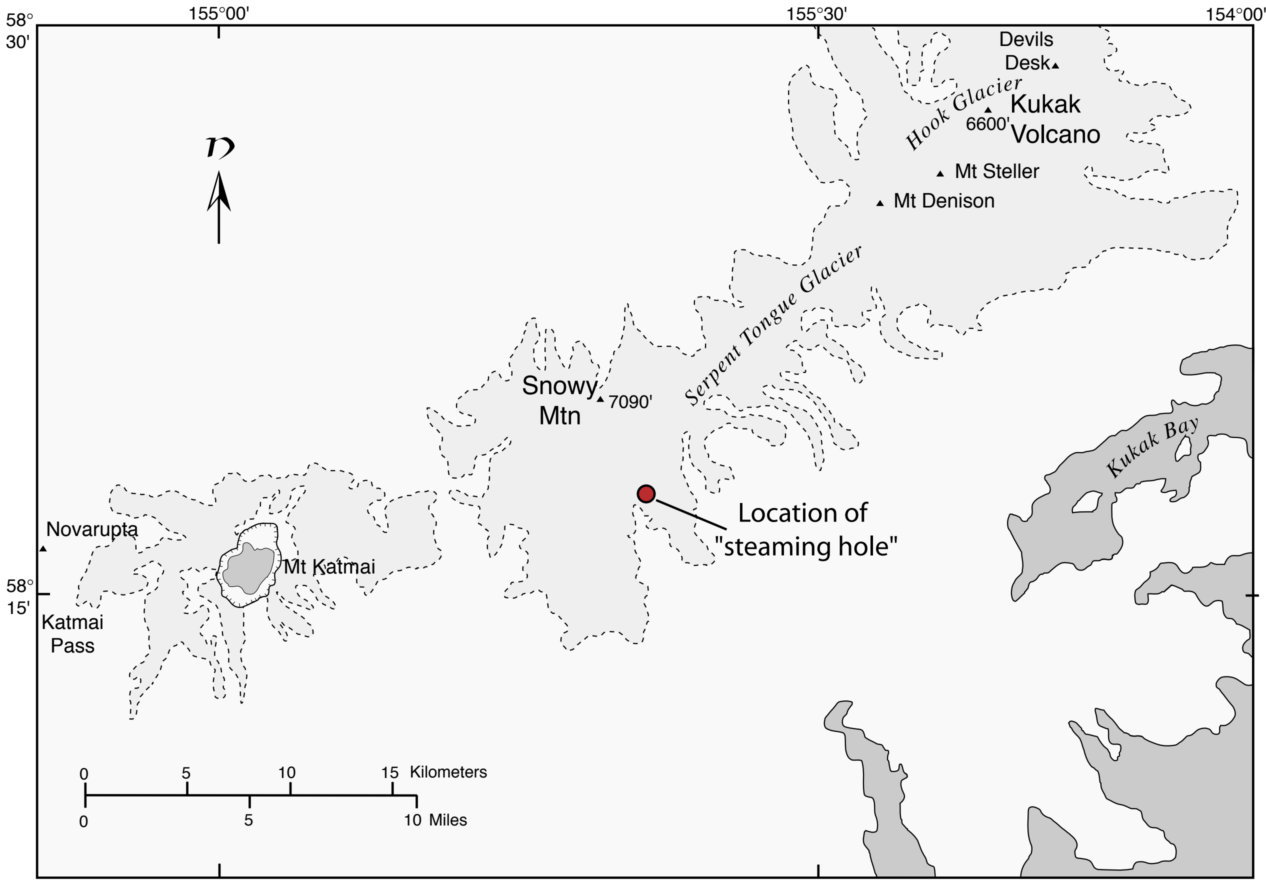


Figure 4. Sketch map showing location of Snowy Mountain and Kukak Volcano with respect to Mt. Katmai. Ice and perennial snow indicated by shaded area bounded by dashed lines; hachured line delineates Katmai caldera. Refer to Figure 1a for area location.

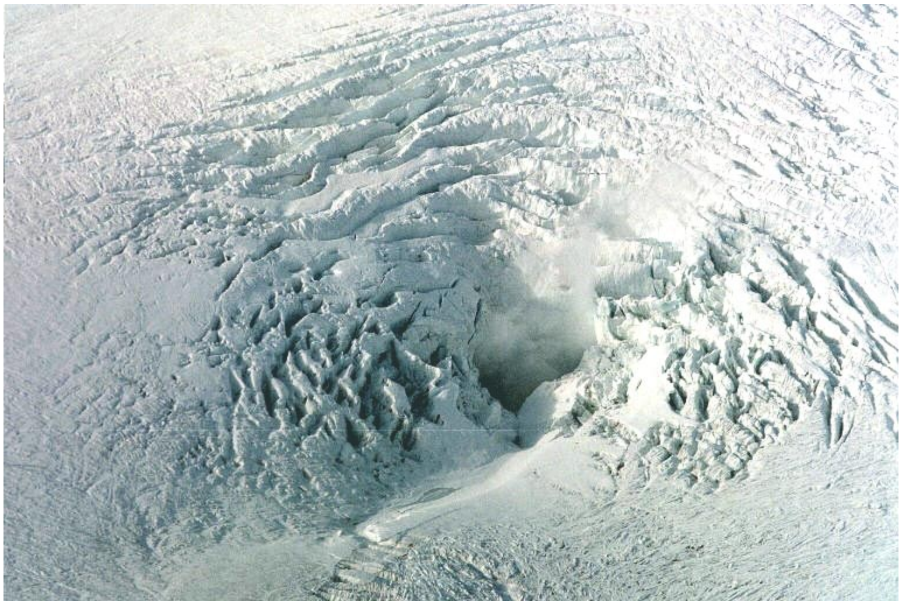


Figure 5. Views of steaming hole in glacier at Snowy volcano on October 8, 2000. The hole was estimated to be about 100-200 meters across with the central orifice 15-30 meter wide. Photographs by John Bundy, NPS.

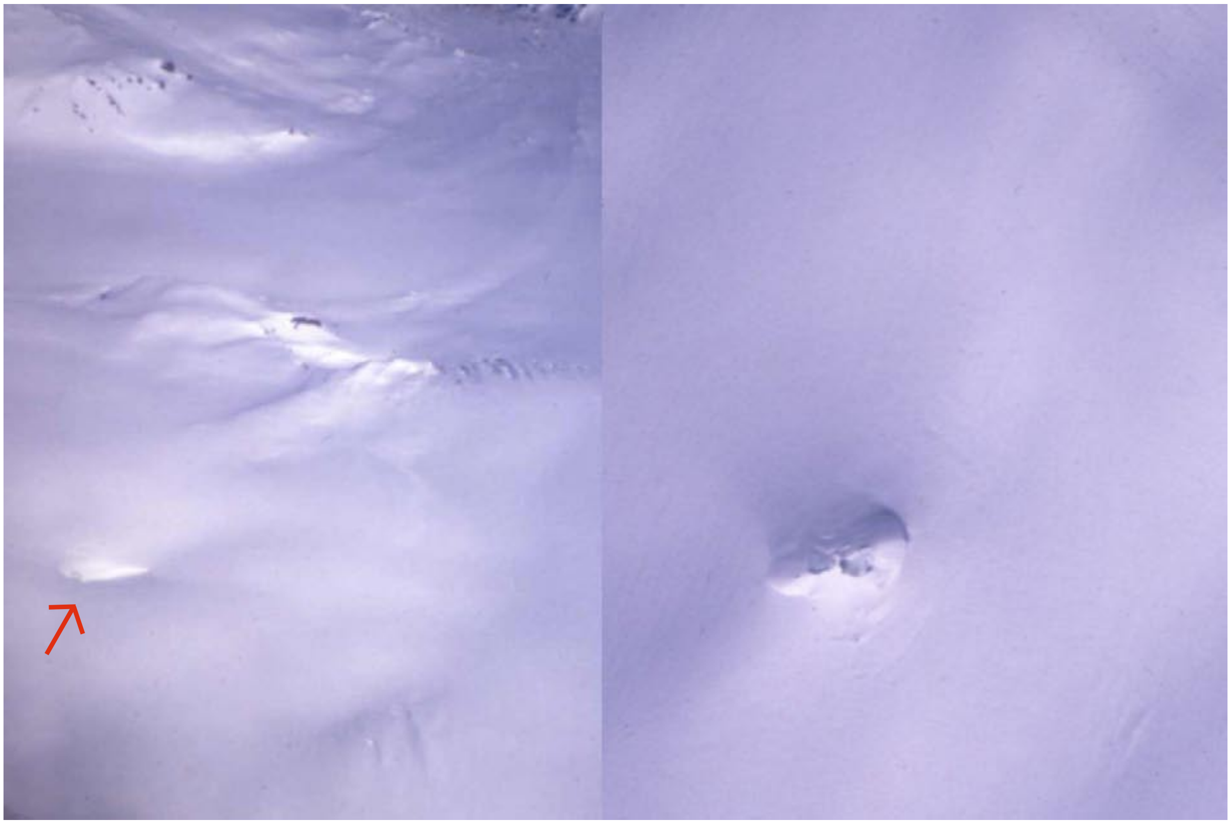


Figure 6. Views of hole in Snowy glacier on June 27, 2001. Left view is oblique and arrow points to the mostly snow-filled depression. Right view is vertical down into the hole. Photographs by Willie Hall.

Hall also reported that he noticed a recent change at the snout of the glacier that contained the hole, where the melt water stream emerges. For the past 5 to 6 years, the stream emerged from the glacier through a large tunnel (which he likened to a railroad tunnel). This year, the tunnel is gone (presumably collapsed) and melt water emerges from multiple small portals spread out along the face of the ice terminus. Hall suggested that the water had been warmer in previous years.

In a follow-up report (Jan. 30, 2002), Hall said that later in the summer of 2001, while on one of his almost daily flights over the Snowy Mountain area, he noticed that the hole (vent) was indeed still active [steaming]. He also reported seeing about 15 vents [fumaroles] on Kukak Volcano, which he described as deep holes in the summit ice field, with most on the upper west flank and about 3 on the east side. In his 23 years of flying over the area he had never seen fumaroles on Kukak before. Wood and Kienle (1990) describe “a vigorous fumarole field on Kukak’s northern peak [that] keeps that area free of ice and reveals the volcanic character of Kukak.” A U.S. Coast Guard helicopter crew reported in June of 1997 seeing steam rising from several vents from a high peak northeast of Mt. Katmai, presumably on Kukak (McGimsey and Wallace, 1999).

Snowy Mountain is a glacier-covered volcanic center comprising a pair (northeast and southwest Snowy) of small andesite-dacite stratovolcanoes (Hildreth and others, 2001). Considered part of the Katmai group, Snowy is located about 17 km (10.6 mi) northeast of Katmai caldera, (fig.

4). Hildreth and others (2001) determined that volcanic activity began at Snowy about 200 ka. Northwest Snowy was last active about 92 ka, and northeast Snowy volcano has erupted at least once during the late Holocene.

Kukak Volcano is located 24 km (15 mi) northeast of Snowy. Although no historic eruptions have been reported, the presence of fumaroles (i.e. a hydrothermal system) and its youthful, non-eroded form, is suggestive of late Holocene eruptive activity (Wood and Kienle, 1990).

PAVLOF VOLCANO
CAVW #1102-03
55°25' N 161°53' W
8,264 ft (2,519 m)

SVA
Reports of steaming, possible ash; sulfur smell

Principal/Teacher, John Concilius, has a good view of Pavlof from his home in Nelson Lagoon (fig. 1). On January 20, 2001 he observed through binoculars steaming from multiple locations near the summit, but none actually at the top of the volcano. He reported that the steam was white and not discolored, and, that the snow near the summit was clean with no evidence of melting. He concluded by stating that this was the most steaming he had seen at the volcano during the past several years and that other villagers considered the steaming to be unusual.

AVO remote sensing specialist Dave Schneider analyzed Advanced Very High Resolution Radiometer (AVHRR) satellite images taken from January 18 to 22, 2001 and found no evidence of increased thermal activity at the volcano and no unusual seismicity was noted. No further reports of steaming were forthcoming. This may have been a meteorological phenomenon.

While working in Cold Bay in early June, Martin LaFevers, Seismic Data Manager at UAFGI, observed and photographed the summit of Pavlof during a weather break; it appeared to be covered with ash (fig. 7). A local pilot reported seeing “something other than steam” at the summit. Again, there was no indication of anomalous seismicity.

Figure 7. Photograph of the summit of Pavlof volcano taken from Cold Bay. View is to the east-northeast and was taken during a weather break, revealing apparent ash covering the summit. Photograph taken by Martin Lafevers (UAFGI), early June, 2001.

NWS observers in Cold Bay contacted AVO on the morning of November 7, 2001 to report a small steam plume originating from the south side of Pavlof; they also received several Pilot Weather Reports (PIREPS) describing the same observation. About a month later, on December 13, 2001, NWS personnel in Cold Bay reported steam issuing from a point about half-way down the south flank of the volcano. The plume rose to a height of about 6,000 ft (~1,830 m) before dissipating. A Pen Air pilot corroborated the report and added that the steaming was coming from a “hill” on the southwest flank; this pilot added that he encountered a strong sulfur smell on a flight by the volcano that day. AVO detected no unusual seismicity or thermal anomalies. Based on conversations with the Pen Air pilot, AVO determined that the source of steaming was likely the fumarole field on nearby Mt. Hague, a late Pleistocene volcano with no historic activity.

Pavlof, the most frequently active of Alaska’s volcanoes (40 eruptions since 1790), is a snow- and ice-covered stratovolcano with a Fuji-like, conical form; a high ridge extends to the south-west and joins the rim of Emmons Lake Caldera. Located 60 km (37 mi) northeast of Cold Bay and 75 km (47 mi) southwest of Nelson Lagoon, near the southwest end of the Alaska Peninsula (fig. 1), the volcano lies above the zone of greatest and most orthogonal convergence along the Aleutian Arc. Pavlof’s last eruption began in September 1996, and continued into January 1997. The strombolian eruption was characterized by lava fountains, lava flows, lahars, and ash plumes to more than 35,000 ft (~10.6 km) ASL causing temporary disruption of air traffic (Neal and McGimsey, 1997). AVO maintains a six-station seismic network installed in 1996 and continues to closely monitor the seismicity and satellite imagery for impending signs of unrest.

FROSTY VOLCANO
CAVW #1102-01
57°08’ N 157°00’ W
7,005 ft (2135 m)

SVA
Rock fall avalanches possibly mistaken for eruptive activity

AVO received several reports during the 2001 summer of possible eruptive activity at Frosty volcano. NWS observer in Cold Bay, Craig Eckert, took photos of what he described as an intermittent steam plume emanating from Frosty on July 8, 2001 (fig. 8). Inspection of records from nearby seismic networks revealed nothing unusual. Two days later, State Trooper pilot, Ron Kmiecik, reported atypical bare rock and dark material at the summit of Frosty, but no venting, steaming, or evidence of melting, specifically mentioning the absence of debris trails or channeling or melted snow. He described the material as a “brown, rusty….not black and ashy like at Pavlof and Shishaldin, like red dust or crushed powder.” In the next several weeks, AVO received a couple of similar reports from local residents and pilots as well as inquiries about the possibility of impending volcanic activity. Craig Eckert reported on August 16 that on the previous day a strong sulfur smell enveloped Cold Bay when the wind was blowing from the southwest (i.e. from the direction of Frosty), and he sent additional photographs to AVO (fig. 9 A-C). On August 28, 2001, AVO scientists working in the area flew over the volcano and observed nothing unusual and no indication of recent volcanic unrest. They noted that snow levels were uncharacteristically low—likely owing to the unusually warm summer—exposing the summit rocks for the first time in many years (fig. 9 C). The newly exposed rocks at the summit, and the possibility (likelihood) of minor rock fall avalanches may have been the cause for mistaken signs of volcanic unrest. They noticed no major landslide deposits, no unusual discoloration, and no sulfur odor.

Frosty volcano, located about 13 km (8 mi) southeast of Cold Bay, is a mid-to late Pleistocene stratovolcano that is now deeply incised by erosion. A possibly Holocene debris-flow deposit rich in hydrothermally altered clasts, derived from the “north crater” of Frosty, extends westward up to 9 km and to within 1 km (0.6 mi) of the sea, and a Holocene ashflow has been identified (Wilson and Weber, 2001).

Figure 8. Apparent steam plume (likely orographic) emanating from the summit of Frosty volcano. Photograph taken by NWS observer Craig Eckert from Cold Bay on July 8, 2001.

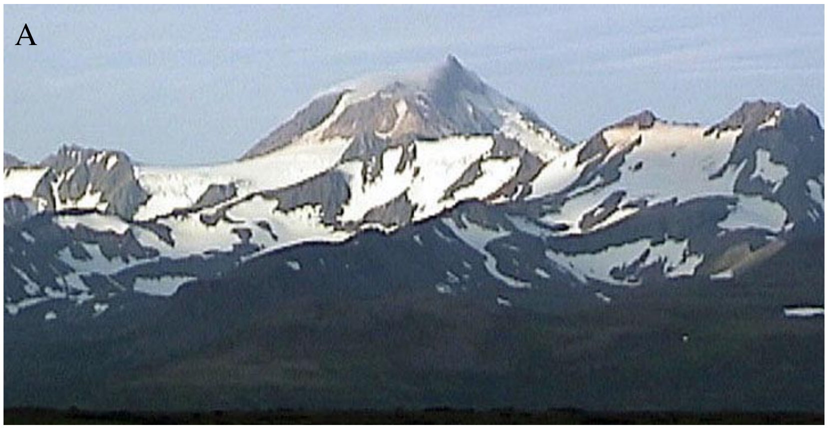


Figure 9. Photographs of Frosty volcano taken by NWS observer Craig Eckert from Cold Bay on August 16, 2001. Photo A shows a distant view and the amount of relative snow cover; B is a telephoto view from the same vantage point; and C is a further telephoto view of the summit area and shows rockslides down the slope below the snow free summit. Compare with Figure 8 for amount of snow melt between July 8 and August 16, 2001.

SHISHALDIN VOLCANO
CAVW #1101-36
54°45’ N 163°58’ W
9,373 ft (2,857 m)

MINOR UNREST
Seismicity increases; steam clouds reported

AVO detected that seismic activity began increasing at Shishaldin Volcano in early June, 2001 and continued through about the end of November, 2001. On April 26, 2001, a pilot reported a steam cloud rising to about 2,000 ft. (~600 m) above the summit. Although the Color Code status of the volcano was never raised above “GREEN”, and the restlessness was not reported in any of our weekly updates, AVO seismologists and remote sensing specialists maintained a close watch on the activity.

Shishaldin Volcano, located about 1,100 km (~680 mi) southwest of Anchorage near the center of Unimak Island, is a spectacular symmetric stratocone that forms the highest peak in the Aleutian Islands (fig. 10). It is one of the most active volcanoes in the Aleutian arc with at least 27 eruptions since 1775 (Miller and others, 1998). The last eruptive period occurred in 1999 and consisted of strombolian fountaining that culminated in a subplinian eruption, which placed an ash cloud to 45,000 ft. ASL (~13,700 m) (McGimsey and others, 2004). Strombolian eruptions and ash and steam emissions characterize most of the documented eruptive activity at Shishaldin Volcano. Nearly constant fumarolic activity within the summit crater produces a steam plume that can occasionally be quite vigorous and typically results in numerous false eruption reports. The nearest community is False Pass, 32 km (20 mi) east-northeast of the volcano.

Figure 10. Aerial view to the south of Shishaldin Volcano. The prominent peak in the background is Westdahl volcano, which is located at the west end of Unimak Island. Photograph by Tina Neal, March 25, 1997.

MAKUSHIN VOLCANO
CAVW #11010-31
53°53' N 166°56' W
5,905 ft (1,800 m)

SVA—ELEVATED SEISMICITY
Slight increase in number of small earthquakes

On February 22, 2001, pilot Joe Polanco reported smelling sulfur and seeing steam issuing from the summit area of Makushin as he flew by. Over the next several months, as tremor from the eruption of Cleveland volcano, 230 km (~145 mi) to the west was being recorded on the Makushin network, AVO seismologists began to suspect that some of the seismicity was actually being generated at Makushin. By May, 2001, it was determined that a real increase in seismic activity beneath Makushin had begun in July, 2000, and on June 1, 2001, AVO included Makushin in the Weekly Update. Earthquakes ranging in magnitude from 0 to 1.5 were occurring at a depth of between 0 and 8 km. AVO continued to closely monitor the activity, which became intermittent by mid-summer and slowly faded back down to background levels through the fall months.

Makushin Volcano (fig. 11) is located on the eastern Aleutian island of Unalaska about 25 km (15.5 mi) west of the city of Unalaska/Dutch Harbor, the most active port in the nation with respect to seafood volume and value. The volcano is a broad, truncated stratovolcano with a 3-km (1.9 mi) -wide summit caldera and a small intracaldera cinder cone. The summit is capped by a 40 km^2 (~15 mi^2) icefield. Makushin is credited with 18 historic eruptions, the latest of which occurred on January 30, 1995 and consisted of a small explosion that produced an ash plume that rose up to 10,000 ft. (~3,000 m) ASL.

Figure 11a. Makushin Volcano viewed from the west. Arrow points to location of summit fumaroloes. Photo by Dave Schneider, April 21, 2001.

Figure 11b. Makushin Volcano viewed from the northeast. Close-up of summit fumaroles. Photo by Dave Schneider, April 21, 2001.

OKMOK VOLCANO
CAVW #1102-29
53°24' N 168°10' W
3,520 ft (1,073 m)

SVA
Earthquake swarm detected May 11, 2001

At 8:00 ADT (16:00 UTC) on the morning of May 11, 2001, AVO seismologists detected on the Makushin seismic network a swarm of earthquakes occurring under Okmok volcano prompting AVO to release an Update at 17:00 ADT (01:00 UTC). The events were ML=2.0-3.6—too small to be felt by nearby residents—and determined to be possibly of volcanic origin. Satellite observations revealed no volcanic activity nor thermal anomalies. On-going satellite-based deformation measurements (SAR interferometry) show that the center of the caldera has inflated 20 cm between the 1997 eruption and September 2000. In April, 2001, AVO scientists observed an area of snowmelt in the caldera,; although possibly indicative of heat flux, the area corresponded to the thickest part of the 1997 lava flow, which may still be hot (Patrick and others, 2003). By May 15, 2001, the earthquake swarm had greatly diminished. Okmok was last mentioned in the May 25, 2001 AVO Weekly Update.

Okmok volcano (fig. 12) is a 10-km-wide (6 mi) caldera located on the eastern end of Umnak Island, 120 km (75 mi) southwest of Dutch Harbor in the eastern Aleutian Islands. The nearest community is Nikiski, population 35, located about 70 km (45 mi) west of the volcano, and a small group of people intermittently occupy buildings at the abandoned Fort Glenn military base located 16 km (10 mi) east of the volcano. Okmok has had several historic eruptions that typically consist of lava flows and ash emissions that occasionally reach above 9,000 m (30,000 ft) ASL. Lava flows crossed the caldera floor from Cone A in 1945, 1958, and 1986 (Miller and others, 1998). The last eruption occurred in February 1997 and was characterized by lava flows and intermittent ash emissions (McGimsey and Wallace, 1999). AVO had no seismic equipment on Okmok in 2001 and the nearest seismic network is at Makushin volcano, located 96 km (60

Figure 12. Okmok caldera as viewed from the Internation Space Station on May 18, 2001. Cone A is the source of most recent eruptive activity; area of snow melt marks the thickest portion of the 1997 lava flow. Image ISS002-E-6065 courtesy of Earth Sciences and Images Analysis Laboratory, NASA Johnson Space Center.

MT. CLEVELAND VOLCANO
CAVW #1101-24
52°49’ N 169°57’ W
5,676 ft (1,730 m)

ERUPTIONS
Early February—early May, 2001; disrupts NOPAC air traffic

Following at least several weeks of visible, but unreported, unrest, Mt. Cleveland volcano erupted explosively on February 19, sending ash to 30,000 feet (~9 km) resulting in several pilot reports of possible encounters with the ash or associated gas cloud, as well as disruption to air traffic along the NOPAC (Dean and others, 2002; Simpson and others, 2002). Two more explosive eruptions—on March 11and 19—also spewed ash across the central Aleutians before the activity began to wane. This was the first significant volcanic eruption in Alaska since the spring of 1999 (McGimsey and others, 2004; Neal and others, 2004).

Mt. Cleveland is a large, symmetric stratovolcano that forms the western half of Chuginadak Island—one of The Islands of Four Mountains Group—located 40 km (25 mi) west of Umnak Island in the central Aleutians (figs. 1, 2, and Cover Photograph). The islands are remote, uninhabited, and without seismic instrumentation. The nearest settlement to Cleveland is Nikolski, about 75 km (~47 mi) east of the volcano on western Umnak Island. Mt. Cleveland is the tallest volcano of the Group and perhaps the most active, with about a dozen reports of historical eruptive activity (Miller and others, 1998). The summit area typically loses snow more rapidly than the surrounding volcanic peaks due to anomalous heat flux (Sekora, 1973). The most recent prior sustained eruption occurred in 1987 and produced minor lava flows as well as steam and ash emissions (Smithsonian Institution, 1987, Miller and others, 1998). Ash clouds and steam were reported on April 29-May 25, 1994, and on May 5, 1997 (Neal and others, 1995; McGimsey and Wallace, 1999). Since AVO has no seismic equipment on Mt. Cleveland volcano, monitoring is conducted by analysis of satellite images and compilation of pilot reports.

The first indication of unrest or eruptive activity at Mt. Cleveland reached AVO on the morning of February 19. Routine satellite imagery taken at 07:55 AST (1655 UTC), made available at approximately 09:15 AST (1815 UTC), and analyzed at about 09:45 AST (1845 UTC), revealed an explosive eruption underway; AVO detected a large (6 pixel) thermal anomaly at the summit and a developing plume. Retrospective analysis of GOES imagery determined that onset of the eruption was at about 05:30 AST (1430 UTC). Pilot reports and additional satellite images later that morning verified that ash clouds were moving in two directions from the volcano. AVO conducted a protocol call-down and issued a Volcanic Activity Report at 10:30 AST (1930 UTC). The FAA issued a SIGMET at 11:19 AST (2019 UTC). The ash plume ultimately rose to 30,000 feet (12 km) within 4.5 hours of onset and became complex, the higher portion--above 17,000 feet--extending to the northwest for 100 km (60 mi), and the lower portion—below 17,000 feet—becoming sheared to the southeast and extending 120 km (75 mi) (fig. 13). A light ash fall, beginning about 12:15 AST (2115 UTC) and lasting about 5.5 hours, was reported in Nikolski.

The eruption was sustained for at least eight hours, and seismometers at Makushin volcano, located about 230 km (143 mi) away, recorded tremor for more than eight hours; satellite imagery suggests ash production lasted for at least 8 hours. The sheared ash cloud was carried northeastward as an elongated ribbon for the next two days, crossing most of the NOPAC routes. By 18:00 AST on February 20 (0300 UTC, February 21), 35 hours after the eruption, the ash cloud was over 1000 km long (620 mi) and extended from Kodiak, Alaska, to Chukotsk Peninsula, Russia (fig. 14). Many intrastate flights in western and southern Alaska were cancelled and trans-Pacific flights were re-routed well north and south of Cleveland (Dean and others, 2002). The FAA issued a 30 km (~20 mi) flight restriction that would stay in effect through the end of May due to uncertainties regarding additional explosive events.

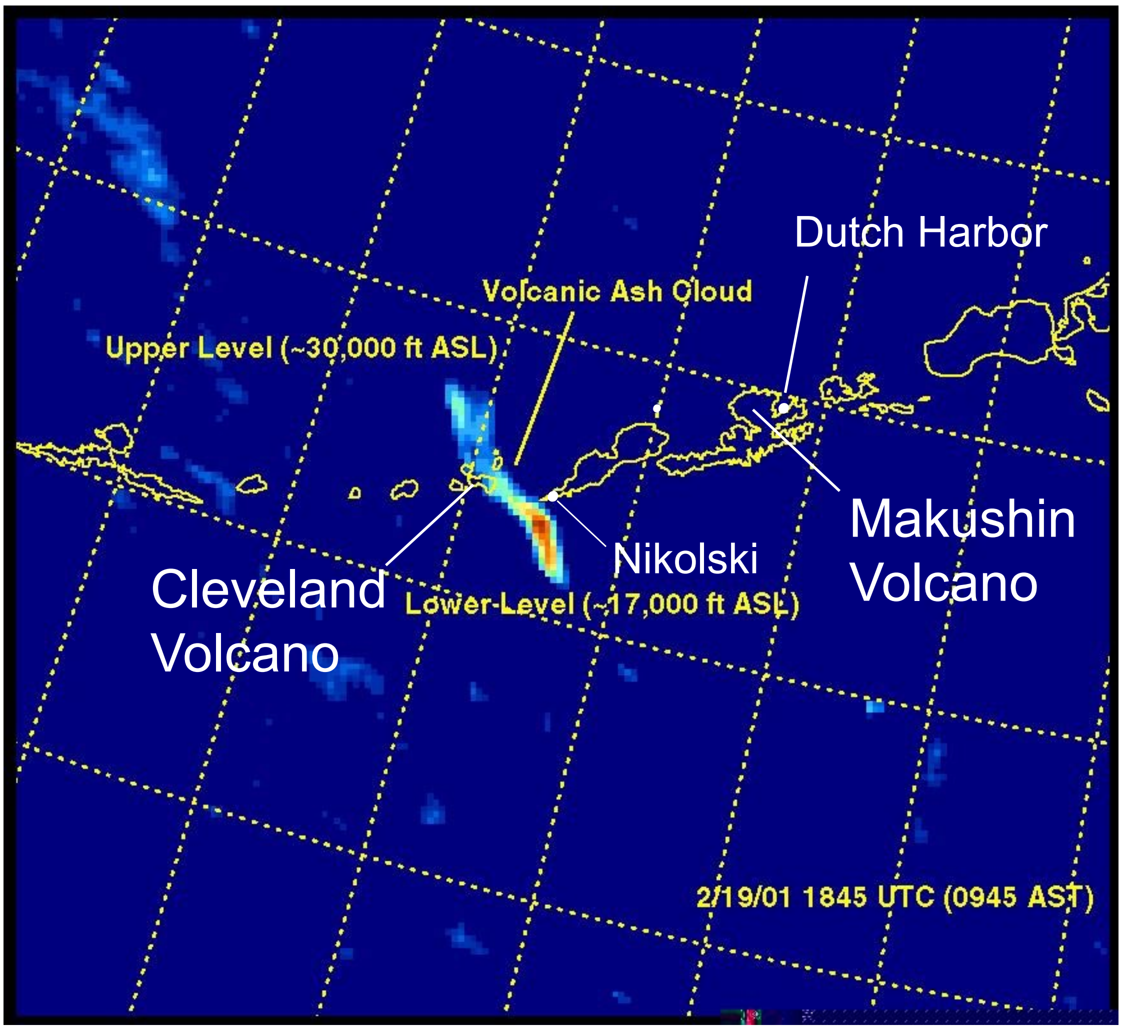


Figure 13. GOES satellite image taken at 09:45 AST (1845 UTC) on February 19, 2001 of the complex ash cloud erupted earlier that morning from Mt. Cleveland volcano. Image provided by Dave Schneider, AVO.

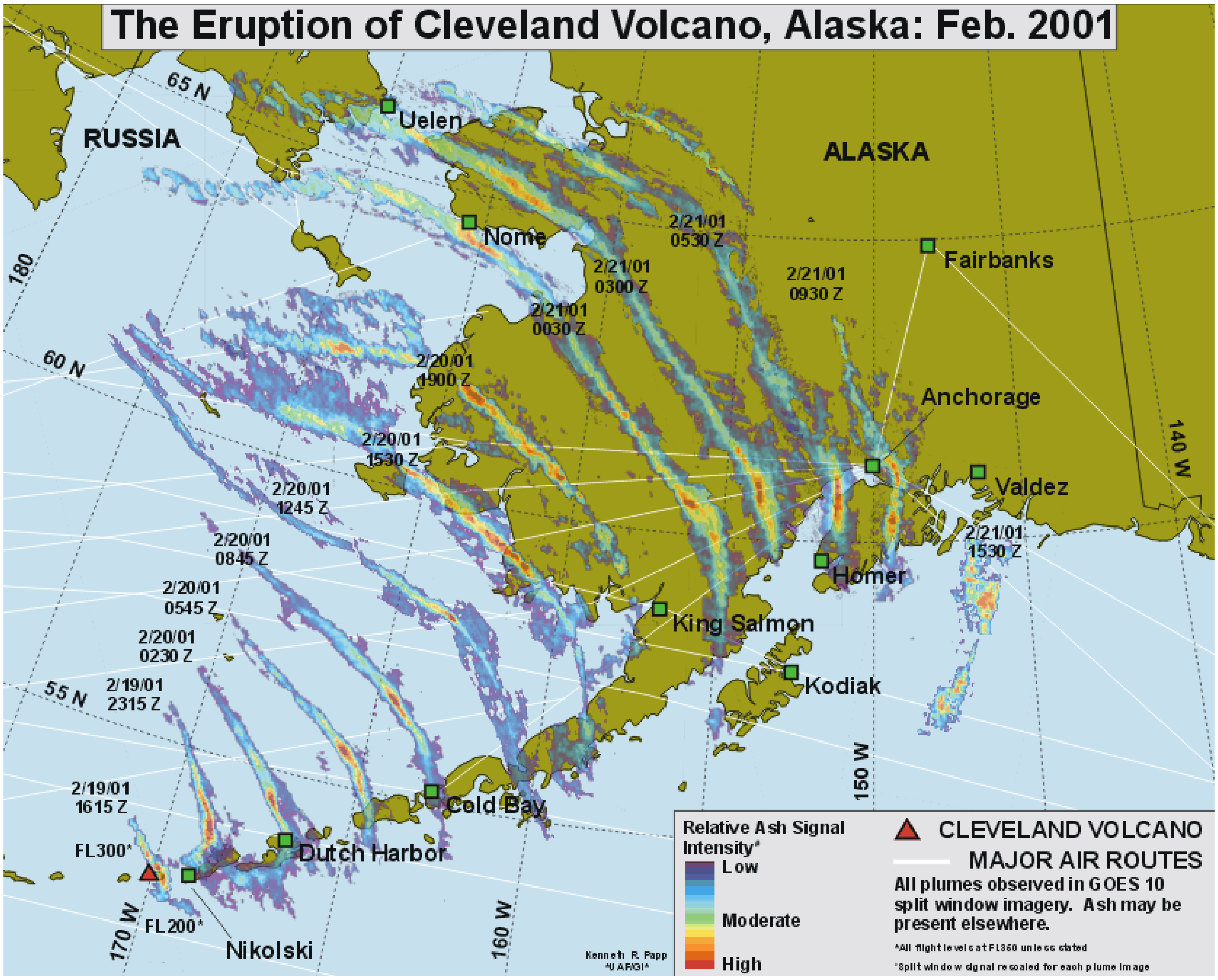


Figure 14. Time-sequential composite of satellite images showing the position of the February 19, 2001 eruption cloud over a 3-day period (February 19, 2001, 07:15 AST [1615 UTC {UTC same as "Z"}] to February 21, 2001, 12:30 AST [0930 UTC)]). The first image is from approximately two hours after the eruption began. The warmer colors indicate higher ash content. Image created by K. Papp. From Dean and others, 2002.

The Puff dispersion model (Searcy and others, 1998), developed for simulated tracking of ash plumes, was used to accurately predict the shape and position of the February 19 Mt. Cleveland ash cloud (Dean and others, 2002, 2004).

Although the February 19 eruption was the first indication of unrest and activity at Mt. Cleveland that AVO was aware of, unreported signs of unrest had been documented earlier in the month. Concomitant with the eruption that morning, AVO received a report and photographs from a pilot who previously observed activity at Mt. Cleveland on February 2 (fig. 15). Retrospective analysis of satellite images shows a possible, but weak and indefinite, thermal anomaly on February 4, one that was not evident in the AVO daily analysis of satellite images.

Figure 15. Photograph of flowage deposit extending down the west flank of Mt. Cleveland volcano on February 2, 2001. Photograph © by Pen Air pilot Dean Cully. Used with permission.

On February 21, a pilot reported that little to no steam was issuing from the summit of Mt. Cleveland, however, a steam source was identified at the southwest shoreline. Photographs showed a lava flow extending from the summit crater down most of the west flank (fig. 16 A). A weak thermal anomaly extending down the western flank was visible on satellite images. Another pilot report on February 22 indicated that a lava flow extended down the west-southwest flank of the volcano from the summit out into the ocean. Subsequent aerial photographs and field observations confirmed that an a'a lava flow and associated agglutinate flow had indeed formed at the summit and descended to nearly the sea (fig. 16 B & C).

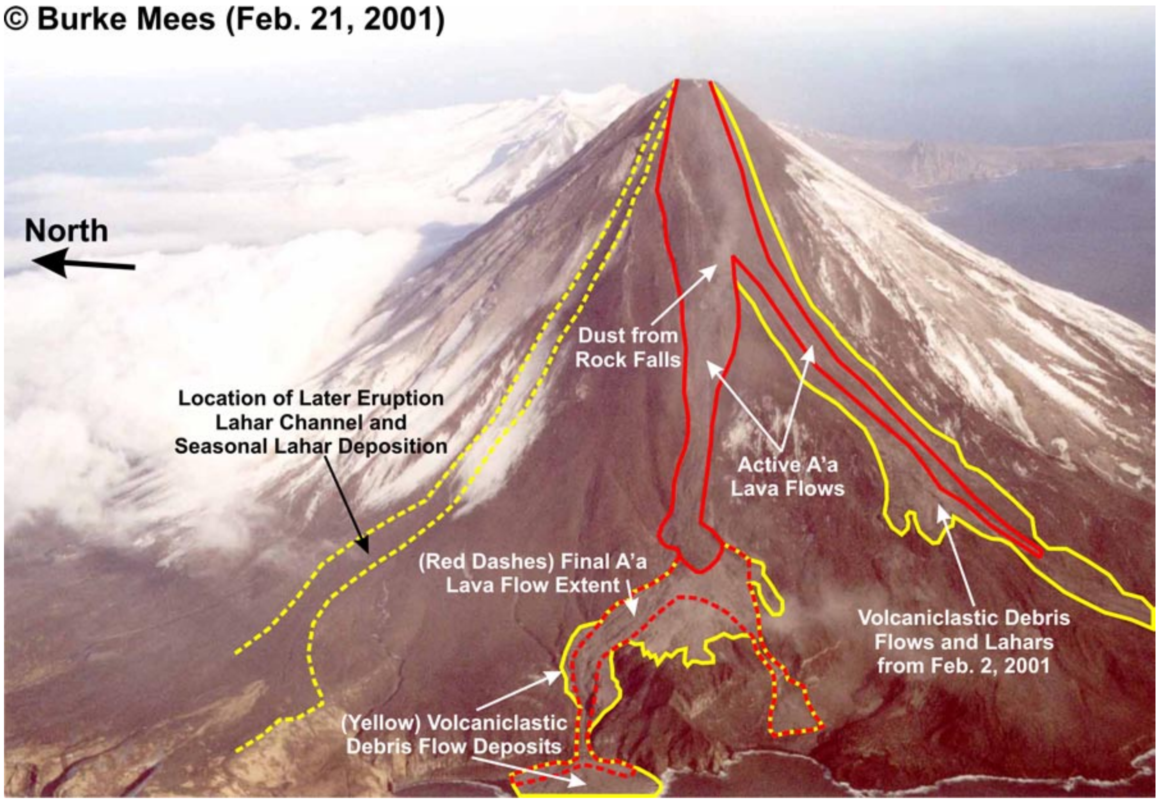
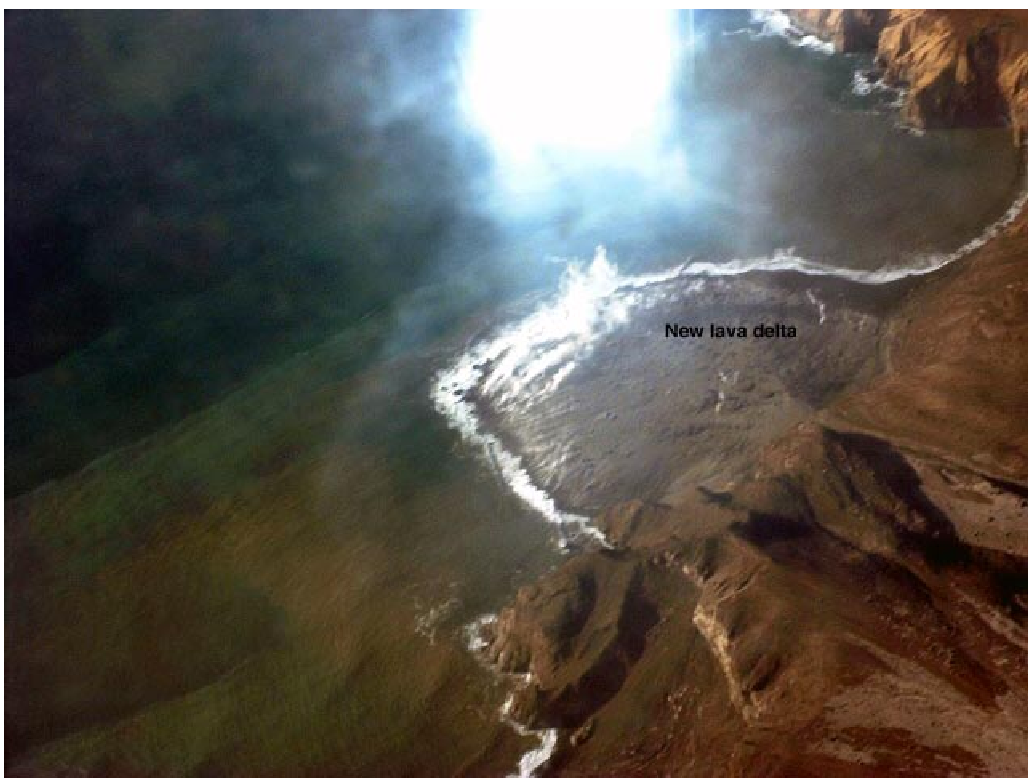


Figure 16. A: The 2001 eruption deposits on the western flank. In this photo taken by pilot Burke Mees (© February 21, 2001) the extent of the eruption deposits as of February 21st (in solid red and yellow lines) is observed. The furthest extent of the 2001 a'a lava flow is in a dashed red line, and the seasonal lahar channel is in a dashed yellow line. Figure from Smith, 2005.

B: Summit crater source of the lava flow down the west flank.



C: Closer view of the newly formed pyroclastic debris flow delta. All photographs © and taken by Pen Air pilot Burke Mees on February 21, 2001. All Used with permission.

AVO Response to the February 19 eruption: Throughout the day of the eruption and for several days after, AVO maintained close communication with collaborating agencies such as the FAA, NWS, DOD, the media, and some air carriers. The AVO-Anchorage crisis room was staffed around the clock on February 19-21; satellite analysis was performed every two hours or more often as images were available during office hours through midday on the 21st, when 24-hour staffing of the AVO-crisis room was curtailed. Satellite tracking was reduced to every four hours on the 23rd. AVO issued eight activity updates by facsimile and electronic mail, the last on February 26. AVO also responded to numerous phone inquiries about the eruptive activity and made daily calls to contacts in Nikolski and to Pen Air dispatch in Dutch Harbor.

By February 23, the thermal anomaly at Mt. Cleveland was no longer detectable. Poor weather obscured the volcano for the next several weeks and there were no further reports on the activity status until March 1 when AVO received a voice message from a Nikolski resident who said she heard reports that Cleveland was "smoking". On March 2, AVO received a report from the flight crew of a Coast Guard C-130 that flew around Cleveland on March 1 and noted that the crater was emitting white steam from the summit that rose about 30 m (100 ft), and that several "dark stripes" extended down the west flank—one all the way to the sea. A 3 1/2-minute VHS video taken by the Coastguardsmen arrived at AVO on March 5. The footage showed that minor eruptive activity had occurred, or, continued, since the photographs taken on February 21. More debris had descended the west-southwest flank and the newly formed delta appeared to perhaps be slightly larger. The flow path for the deposit (flow) shown in the February 2 photograph (fig. 15) had widened, and a second deposit paralleled the earlier deposit (flow). The upper flank, immediately down slope from the vent, was littered with debris from ballistic showers and tumble paths from blocks that rolled down the slope.

Lack of any further activity prompted AVO to announce in the Friday, March 9, 2001 Weekly Update that Cleveland would no longer be mentioned in routine updates unless the situation changed. Then, on March 11 at approximately 05:00 AST (1400 UTC), based on retrospective analysis of GOES satellite imagery, another explosive eruption began at Mt. Cleveland placing a column of ash up to 8 km (5 mi) above the volcano and adding more material to the hot flow deposit on the west flank (fig. 17). Subsequent analysis of AVHRR data showed a strong thermal anomaly on the west flank. A week later, a Landsat scene taken during the eruption was obtained that shows the extent of the thermal feature (D. Schneider, written communication, Dean and others, 2002)(fig. 17).

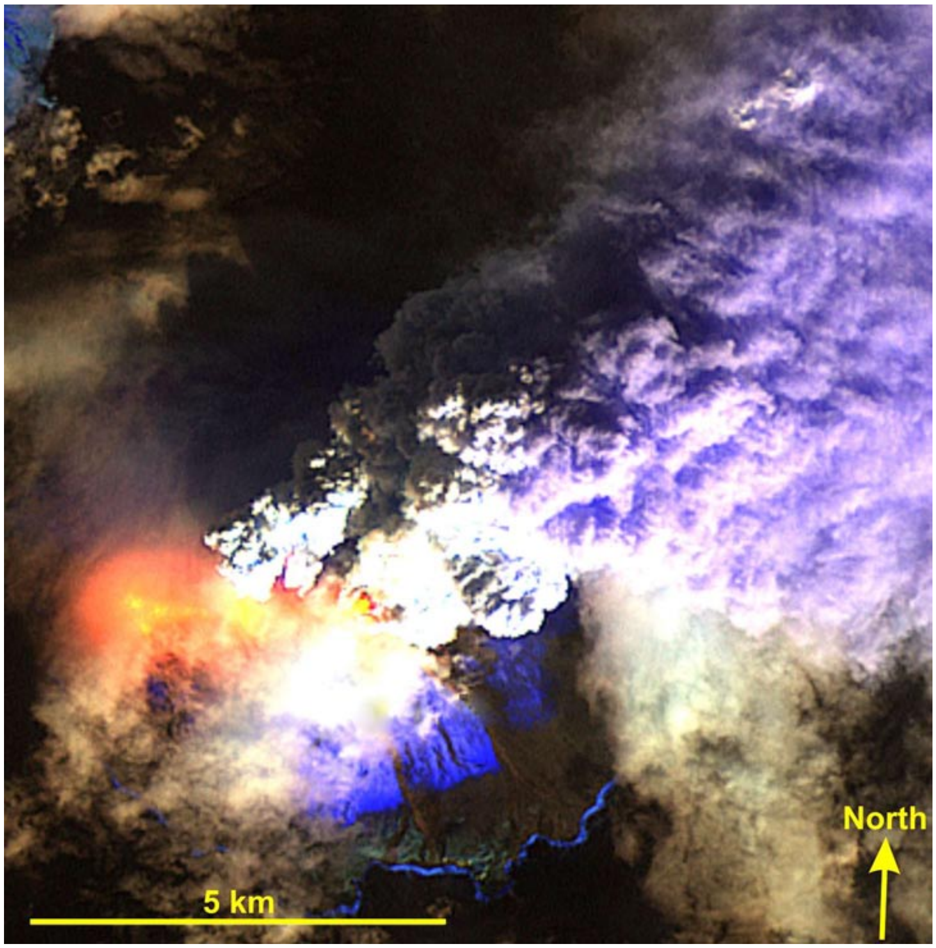


Figure 17. Landsat 7 Enhanced Thematic Mapper satellite image of the March 11, 2001 eruption of Mt. Cleveland. The false color image shows a hot deposit—presumably the lava flow—on the west flank of the volcano (yellow and orange), the plume blowing to the northeast, and snow (blue) on the south and southeast flanks of the volcano. This data is from 13:30 AST (2230 UTC), ash production is over, and the plume is mainly steam. Image provided by Steve Smith, AVO, after Dean and others, 2002.

AVO detected the eruption at 14:28 AST (2328 UTC), and a protocol call-down was initiated at 14:40 AST (2340 UTC). A Volcanic Activity Report was issued at 15:30 AST (0030 UTC, March 12). The eruption lasted 3 hours (05:00 to 08:00 AST, 1400 to 1700 UTC) and seismic tremor was recorded for eight hours on the nearest station, located 230 km (143 mi) northeast at Makushin Volcano. The ash cloud extended up to 760 km (~470 mi) east of Mt. Cleveland by early-afternoon on March 12 (fig. 18), and had drifted further northeast for over 1000 km (~620 mi) by March 13, 42 hours after the eruption (Dean and others, 2004). No ash fall was reported. FAA issued a SIGMET but no reported disruption of air traffic occurred, presumably because the ash cloud was confined to a relatively low altitude, and was carried mostly over oceanic areas south of local flight paths. The Puff model (Searcy and others, 1998) accurately predicted plume height and ash dispersal (Dean and others, 2002).

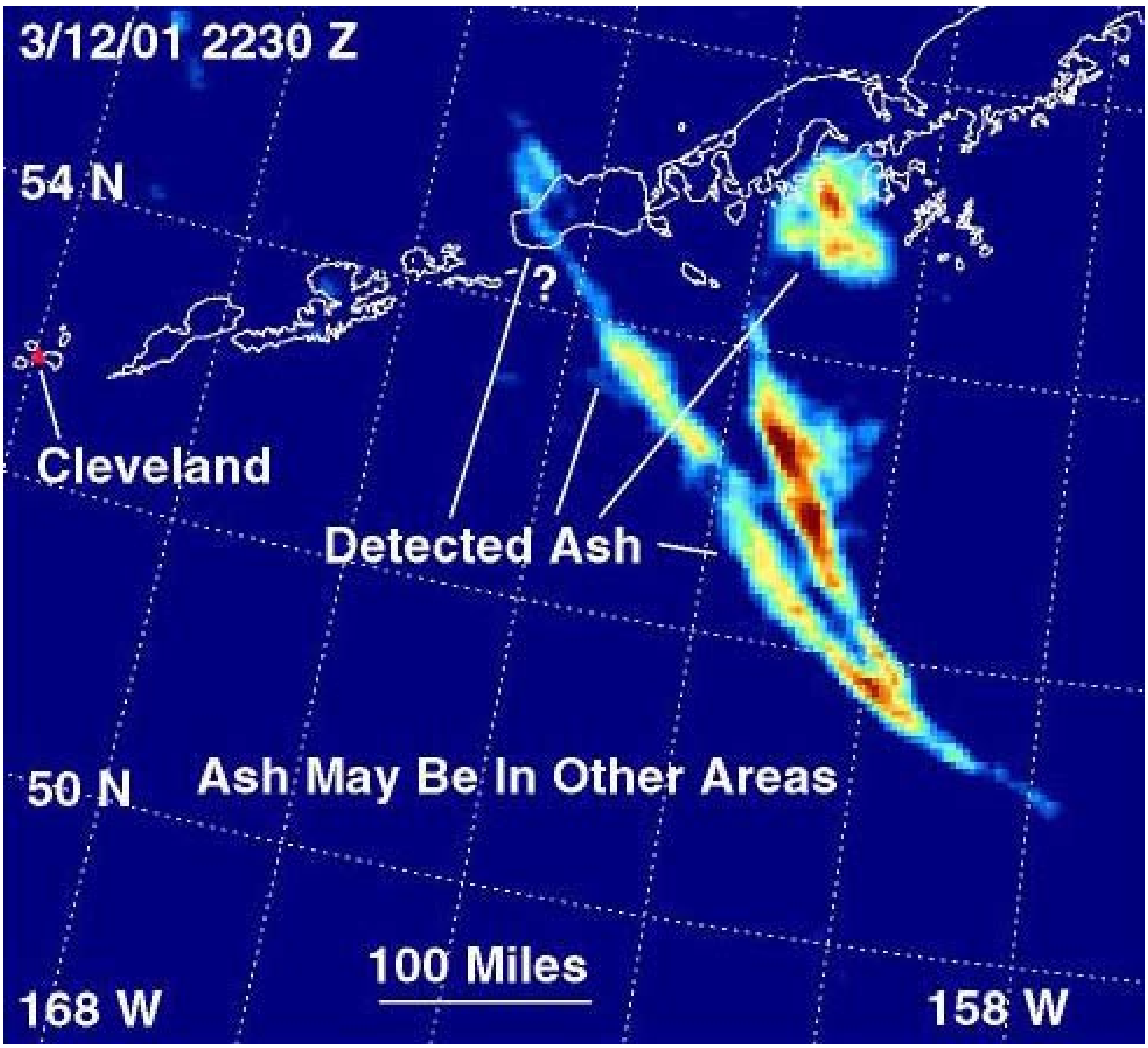


Figure 18. GOES satellite image of ash cloud from Mt. Cleveland volcano, taken 13:30 AST (2230 UTC) March 12, 2001. Image provided by Dave Schneider.

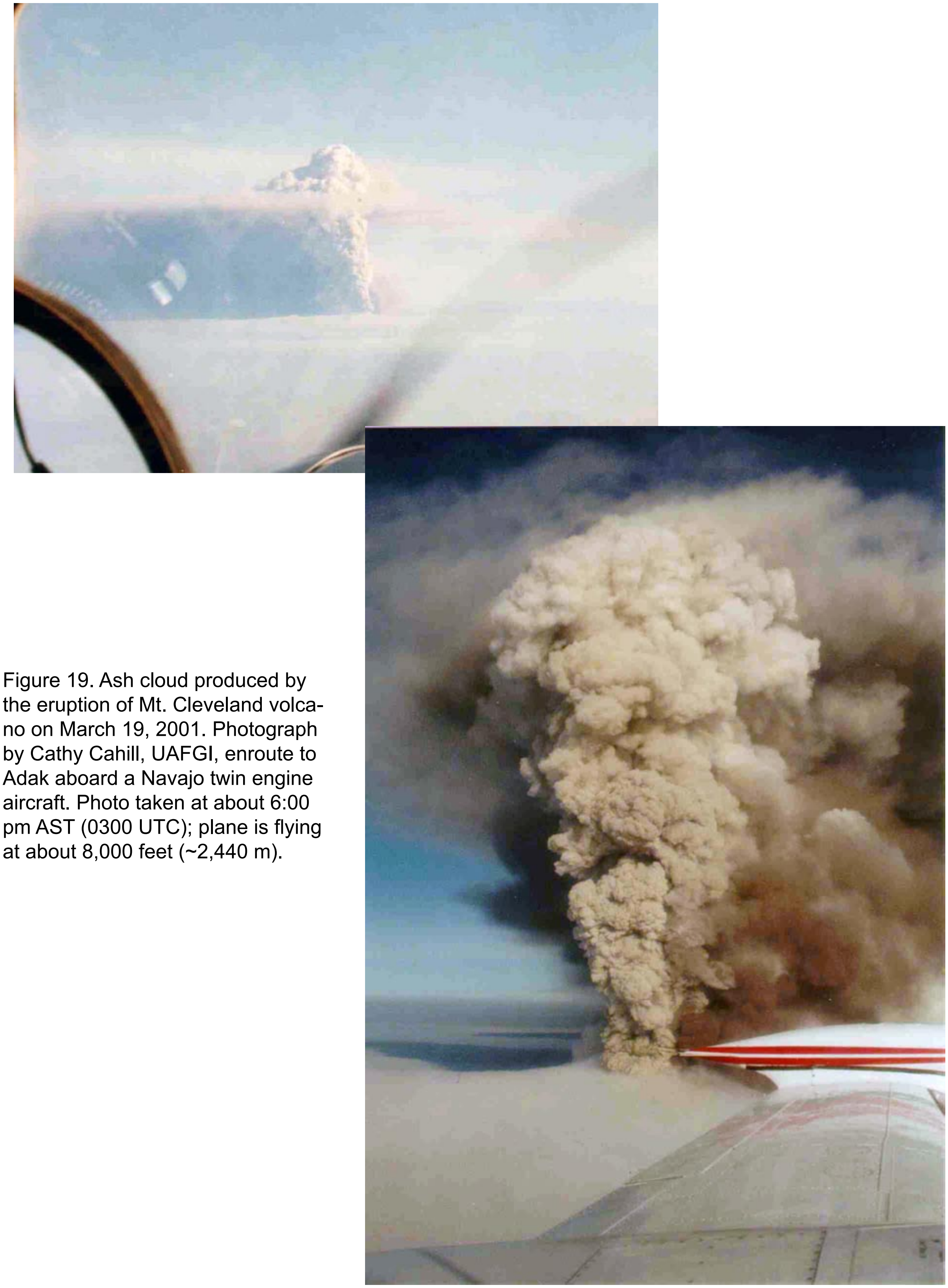


Figure 19. Ash cloud produced by the eruption of Mt. Cleveland volcano on March 19, 2001. Photograph by Cathy Cahill, UAFGI, enroute to Adak aboard a Navajo twin engine aircraft. Photo taken at about 6:00 pm AST (0300 UTC); plane is flying at about 8,000 feet (~2,440 m).

Prompted by the AVO call-down, FAA placed a temporary flight restriction (TFR) around Mt. Cleveland, which was subsequently cancelled on the morning of March 20. Later, in the afternoon of March 20, FAA issued an International and Domestic NOTAM and reinstated the TFR (10 miles radial and up to 60,000 ft; 18 km) to caution pilots and dispatchers of possible further eruptive activity from Cleveland. Eastbound NOPAC tracks were re-routed, and the Tokyo Center had to re-route many planes. By the morning of March 20, most westbound planes diverted well south of the volcano.

Thermal anomalies were detected in satellite images during fair weather conditions for about the next three weeks as the eruptive activity waned. AVO last reported on Mt. Cleveland in the May 25, 2001 Weekly Update. The 2001 eruption of Mt. Cleveland served as a case study of the monitoring of volcanic eruptions and subsequent dispersal of ash clouds utilizing satellite images (Dean and others, 2004).

GREAT SITKIN VOLCANO
CAVW #1101-12
52°05’ N 176°08’ W
5,709 ft (1,740 m)

SVA
Anomalous seismicity

Beginning in early February, 2001, seismicity at Great Sitkin volcano began to increase. The activity came to an abrupt end by the end of the month. The next seven months was characterized by short-lived seismic swarms that ended as quickly as they began, most only a day or two in duration. The largest swarm (15 events) occurred on Saturday, August 18, 2001.

Great Sitkin Volcano is an 8 by 11 km (5 by 7 mi) stratovolcano that forms the northern half of uninhabited Great Sitkin Island in the central Aleutian Islands (figs. 1 and 20), and is located about 35 km (22 mi) northeast of the community of Adak on Adak Island, and 130 km (8 mi) west of the community of Atka on Atka Island. The volcano comprises a young parasitic cone hosting a summit crater, which sits on the west flank of an older, deeply eroded volcano. A steep-sided young (1974) dome sits in the center of the crater (Miller and others, 1998; Waythomas and others, 2003). At least eight historic eruptions are recorded for Great Sitkin with the most recent occurring in 1974, causing minor ash fall on the flanks and emplacement of a lava dome in the summit crater. At least eight explosive eruptions that produced extensive pumice-rich lapilli tephra have occurred in the past 9,000 years with one having occurred within the last 500 years (Waythomas and other, 2003). Recent work by Waythomas and others (2003) also discovered evidence for a large-scale pre-Holocene collapse of a large northwestern portion of the older volcanic cone.

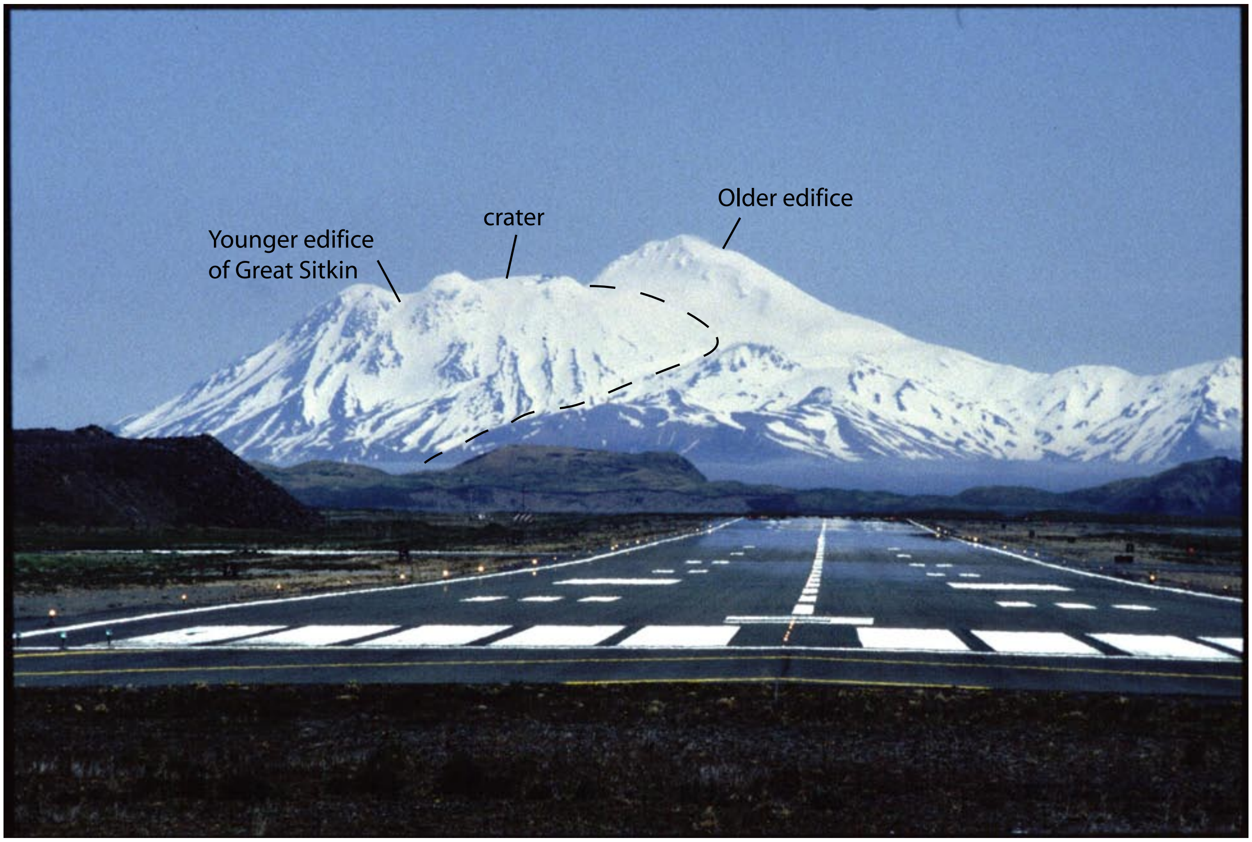


Figure 20. Great Sitkin Volcano from the north shore of Adak Island. Photograph by Chris Nye, July, 2000.

VOLCANIC ACTIVITY, KAMCHATKA PENINSULA, RUSSIA

Twenty-nine active volcanoes on Russia's Kamchatka Peninsula pose a serious threat to aircraft in the North Pacific (fig. 21). By agreement with the Institute of Volcanic Geology and Geochemistry (IVGG) and the Kamchatka Experimental and Methodical Seismology Department (Kamchatka Experimental and Methodical Seismology Department), both Institutes of the Russian Academy of Sciences, AVO assists with global distribution of information about eruptions in Russia (Kirianov and others, 2002). The Kamchatkan Volcanic Eruption Response Team (KVERT), consisting of scientists from both IVGG and KEMSD, issues via e-mail a weekly information release which AVO posts to our website and disseminates via facsimile and e-mail to recipients of our Alaska Volcanoes weekly updates. When volcanic activity intensifies at any Kamchatkan volcano requiring notification of aviation interests, KVERT sends updates during the week as needed. Standard KVERT weekly updates—called Information Releases—are rebroadcast by AVO usually on Thursdays (Friday in Kamchatka). In its 2001 weekly reports, KVERT routinely reported on Sheveluch, Klyuchevskoy, Bezymianny, Karymsky, Avachinsky, and Koryaksky, and Mutnovsky and Gorely Volcanoes.

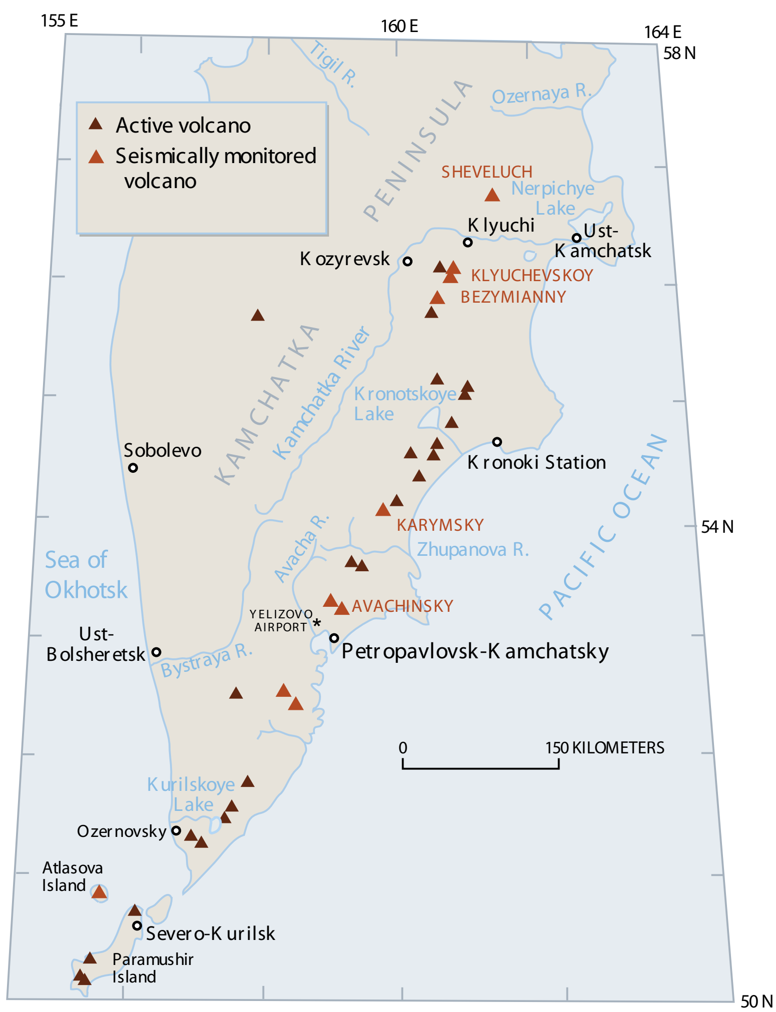


Figure 21. Map of Kamchatka Peninsula and northern Kurile Islands. Volcanoes discussed in this report are labeled in red.

Beginning in late November 2001, KVERT began including a brief summary listing of Kamchatkan volcanoes and color codes at the top of the narrative weekly updates. Volcanoes at GREEN were not described in great detail in the body of the information release to reduce text bulk. Another development in KVERT reporting occurred in early 2001 when EMSD staff member Yuri Demyanchuk stationed in Klyuchi began sending digital photos of Sheveluch Volcano to AVO via e-mail.

The KEMSD portion of KVERT monitors most of the frequently active volcanoes in Kamchatka with one or more short period seismometers. In addition, KVERT receives visual report of activity from scientific observers in the communities of Klyuchi (pop. ~10-15,000, ~45 km or ~28 mi southwest of Sheveluch) and Kozyrevsk (pop. ~2-3,000, ~50 km or ~31 mi west of Klyuchevskoy) to the north and west of the Klyuchevskoy group of volcanoes. On occasion, KVERT also receives reports from observers near Karymsky Volcano, and pilot reports are increasingly available from the local Civil Aviation Meteorological Center at Yelizovo Airport. AVO sends KVERT summaries of satellite information on the presence of thermal anomalies or ash plumes when detected as part of AVO's daily satellite monitoring program. AVO makes some of these image data available directly to KVERT via ftp as well, for their own analysis. Sometimes, KVERT sends significant MODIS-satellite images from Yuzhno-Sakhalinsk to AVO.

In 2001, AVO processed information about eruptions and volcanic unrest at 5 Kamchatkan volcanoes, four of which continued periods of unrest extending over several years. For each of these periods of heightened activity, AVO relayed information from KVERT to aviation and weather authorities and hundreds of other recipients through standard notification procedures. In addition, AVO staff communicated directly with KVERT to clarify and verify information and assist users in interpreting data coming from KVERT.

The following summaries contain reported events according to Kamchatkan local dates and Coordinated Universal Time (UTC), which equals ADT + 8 hrs and AST+9 hrs. The equivalent local Kamchatkan time (herein referred to as Kamchatkan Daylight [KDT] or Standard time [KST]) is always 21 hours ahead of Alaska time. This compilation of summary descriptions is derived from a number of sources including KVERT weekly updates (available online at: http://www.avo.alaska.edu/avo4/updates/kvertarch.htm) , unpublished AVO internal files and documentation, Smithsonian Institution Global Volcanism Program reports online (http://www.volcano.si.edu/reports/). Readers are referred to the publicly available sources listed above for greater detail.

SHEVELUCH VOLCANO
CAVW #1000-27
56°38' N 161°21' E
3,283 m (10,768 ft)
Kamchatka Peninsula

Lava dome growth and instability continued in 2001. Short-lived explosions send ash as high as 10 –11 km (~33,000 – 37,720 ft) ASL on May 19, 21, and September 30. Dome collapse events produce pyroclastic flows and local ash fall. Ongoing shallow seismicity and volcanic tremor, fumarolic plumes.

Eruptive activity related to growth of the lava dome at Sheveluch Volcano continued intermittently through 2001. During periods of relative quiet, background seismicity consisted primarily of weak, small earthquakes within the volcano edifice and occasional tremor beneath the lava dome complex. At other times, seismicity varied in intensity as indicated by the number of shallow earthquakes or the amplitude of tremor. KVERT changed the level of concern color code for Sheveluch 13 times during the year.

Several brief episodes of heightened activity were recorded during the year. On March 7, seismicity indicated an explosion from the volcano and a pilot reported an ash plume ~10 km (~33,000 ft) ASL extending ~30 km (~19 mi) northeast from Sheveluch. A plume extending ~50 km to the north was noted in a satellite image at 05:15 UTC on March 7.

In late April, KVERT noted that seismicity had increased sharply in a pattern similar to that observed prior to the major April 1993 explosive eruption that sent ash to 20 km (~66,000 ft) ASL (Smithsonian Institution, 1993). Accordingly, KVERT elevated the Color Code to ORANGE on April 24. Over the next several weeks, seismicity remained above normal and AVO began to detect a growing thermal anomaly in the vicinity of the active dome complex. A small (4,500 m or 14,800 ft. ASL) ash plume and pyroclastic flow deposits were observed from Klyuchi on May 7 accompanied by strong tremor. A light ash fall occurred in Klyuchi and AVO noted a ~40-km-long (~25 mi) ash plume on satellite images. Observers in Klyuchi made visual confirmation of new extrusive lava dome material on May 12 (fig. 22). Sheveluch erupted explosively on May 19 sending ash to 10 km (~33,000 ft) ASL. Pyroclastic flows were shed from the dome complex. Explosions of this magnitude and larger (a 10-12-km-high [~33,000 - 39,400 ft] plume was reported on May 21) continued through May 22 and Sheveluch remained at RED for much of this time (fig. 23).

Figure 22. May 16, 2001 oblique aerial photograph of the active Sheveluch lava dome. Lava dome is approximately 330 m high and 1 km across. Photo by Yuri Demyanchuk, KEMSD.

Figure 23. Eruption cloud rises approximately 12 km ASL above Sheveluch Volcano on May 21, 2001. View to the northeast from the town of Kliuchi. Photo by Yuri Demyanchuk, KEMSD.

AVO tracked an intensifying thermal anomaly that coincided with sightings of incandescence from Klyuchi. The shape and extent of the anomaly likely reflected hot material near the main vent and in the adjacent pyroclastic debris fan. By May 24, much of the new dome seen on May 12 had been destroyed. On May 30, with seismicity decreasing, KVERT reverted to YELLOW.

Despite lower seismicity, dome growth accompanied by avalanches of hot debris, localized ash fall, and occasional explosive production of ash plumes continued through the end of the year. KVERT upgraded the color code to ORANGE on July 19 and to RED for 24 hours on September 30 following an explosive event that sent ash to 11.5 km (~38,000 ft) ASL and dusted Klyuchi with ash. After six more weeks at ORANGE, KVERT downgraded to YELLOW for the final five weeks of the year. Occasional explosions and short-lived ash plume production continued.

For each of these periods of heightened activity, AVO relayed information from KVERT to aviation and weather authorities and hundreds of other recipients through standard notification procedures. In addition, AVO staff communicated directly with KVERT to clarify and verify information and assist users in interpreting data coming from KVERT.

Many of the ash clouds from Sheveluch were observed on satellite imagery and detected during routine analysis by AVO and by KVERT. Thermal anomalies related to the growing and collapsing dome, as well as hot pyroclastic material on the debris apron southwest of the active dome, were also detected and reported by AVO through the end of the year.

During periods of lower seismicity and in between explosive events, a fumarolic plume was occasionally visible over the lava dome rising typically to altitudes of 50 – 1000 m (~160–3,300 ft) above the dome (fig. 24). These plumes were visible downwind tens of kilometers. At times, no plume was present. On July 3-5 and October 30, particularly vigorous fumarolic plumes were reported to reach 4-4.5 km (~13,000–14,800 ft) ASL.

Figure 24. Telephoto view from Kliuchi of the active lava dome at Sheveluch on October 14, 2001. Photo by Yuri Demyanchuk, KEMSD.

Sheveluch Volcano is one of the largest and most active volcanoes in Kamchatka with at least 60 large eruptions during the Holocene (Ponomareva and others, 1998). The northernmost active volcano on the Peninsula, historical eruptive activity has been characterized by lava dome growth and explosive collapse, often producing directed-blasts (Bogoyavlenskaya at al., 1985). Its current protracted, episodic, phase of lava dome growth began in August of 1980.

KLYUCHEVSKOY VOLCANO
CAVW #1000-26
56°03' N 160°38' E
4,750 m (15,589 ft)
Kamchatka Peninsula, Russia

Periods of elevated seismicity, persistent fumarolic plume from summit crater. Several periods of increased seismicity but no explosive eruptions.

Klyuchevskoy Volcano remained restless in 2001 with periods of elevated seismicity when KVERT raised the level of concern color code briefly to YELLOW (March 16, April 8, November 16). Throughout the year, an intermittent fumarolic plume ascended 50–2,500 m (~160-8,200 ft) above the summit and drifted downwind as much as 100 km (62 mi). A possible one-pixel thermal anomaly was noted at the volcano on August 21 and non-ash bearing plumes from Klyuchevskoy were detected in satellite imagery on March 4 and September 24.
Klyuchevskoy is a classic stratovolcano and, at 4750 m (15,589 ft), the highest of the active European and Asian volcanoes. It is frequently active with vulcanian to strombolian explosions and occasional lava flow production from the main vent in the steep-walled summit crater or from flank vents (Khrenov et al., 1991). Explosive eruptions are recorded in nearly every decade and at multiple times during most years since the early 1700s (Simkin and Siebert, 1994). Prior to 2001, the most recent significant eruption was September 30-October 1, 1994.

BEZYMIANNY VOLCANO
CAVW #1000-25
55°58' N 160°36' E
2,800 m (9,187 ft)
Kamchatka Peninsula, Russia
Two periods of accelerated lava dome growth and related explosions, pyroclastic flows and avalanches.

KVERT reported background or below background seismicity at Bezymianny for the first seven months of 2001. A fumarolic plume rose intermittently over the volcano 50-800 m (~160-2600 ft) and trailed downwind 10 - 30 km (~6-20 mi). The Tokyo Volcanic Ash Advisory Center (VAAC) issued a volcanic ash advisory statement for a 'possible' eruption at Bezymianny on June 6; ultimately consensus was that the cloud noted on GMS imagery was probably orographic in nature. KVERT was contacted and confirmed no unusual seismicity. Real time video images of Klyuchevskoi also showed no activity in the vicinity.

Relative quiescence changed abruptly in late July when seismicity began to increase and KVERT noted signals related to avalanches of debris, likely related to new extrusion at the lava dome. At the same time, AVO noted the sudden appearance of a thermal anomaly in the vicinity of the dome and extending in a linear zone to the southwest. KVERT declared color code ORANGE on July 27 two days after the onset of increased seismicity. On August 7, KVERT declared color code RED after a series of explosions sent ash to an estimated 10 km above the volcano (12.8 km or ~42,000 ft ASL). This ash cloud ultimately was tracked by satellite moving ESE at least 200 km (~120 mi). Ash fall from this event was reported at Kronoki Station (~160 km or 100 mi SSE of Bezymianny on the Pacific coast of Kamchatka). Thermal anomalies on August 9-10 were interpreted to reflect new lava flow at the dome. Dome collapse signals continued for several days but an overall decrease in activity prompted a return to GREEN on August 10.

A second burst of activity followed detection of a thermal anomaly noted by KVERT in AVHRR images on December 10, along with a fait plume extending 87 km (~54 mi) southeast from Bezymianny. A robust fumarolic plume and intensifying thermal anomaly prompted color code ORANGE from Dec 14-25, but no explosive dome collapse event ensued. On December 16, a plume that appeared dark from a distance reached 4 km (~13,000 ft) above the dome and drifted 60 km (~37 mi) downwind. Thermal anomalies were observed occasionally during December. Through the end of the year, the anomaly continued to decrease in size, seismicity returned to background, and KVERT reverted to GREEN on December 28. .

In October 1955, Bezymianny Volcano emerged from a 900-1000 year period of quiescence commencing an explosive eruption that culminated on March 30, 1956, with the catastrophic failure of the eastern flank and debris avalanche and lateral blast similar to what occurred at Mount St. Helens in 1980 (Voight and others, 1981). Since then, lava extrusion has produced a dome that periodically collapses generating pyroclastic flows and short-lived ash plumes that occasionally are carried into U.S. air space over the Western Aleutians (Girina and others, 1993). Bezymianny is one of the most active volcanoes on the Kamchatka Peninsula.

KARYMSKY VOLCANO
CAVW #1000-13
54°03’ N 159°27’ E
1,486 m (4,876 ft)
Kamchatka Peninsula, Russia

Continuation of low-level vulcanian and strombolian eruptions, explosions, avalanches, degassing.

2001 was a fairly quiet year for Karymsky. Seismicity remained at background with fluctuating levels of small local earthquakes and periods of tremor until late October when the number of detected events increased. On November 16, KVERT elevated the color code from GREEN directly to ORANGE after a 20-min seismic event, possibly signaling an explosive eruption, occurred (fig. 25). Based on the amplitude of seismicity, KVERT estimated ash may have reached 8 km (~26,000 ft) ASL. Seismicity continued at rates above background and included local earthquakes and periods of tremor, and possibly additional small explosions. One week later, as seismicity declined but remained above background, KVERT lowered the level of concern to YELLOW. A helicopter crew in the area reported that the upper part of the edifice of Karymsky was 'black'. KVERT observers also noted on November 22 that the summit area was free of snow and steaming vigorously. KVERT maintained YELLOW through the end of the year; small explosive events detected seismically continued. Between 26-80 local seismic events were recorded each day.

Figure 25. November 2001 oblique aerial photograph of the summit crater of Karymsky. The summit and upper flanks of the volcano are mantled by tephra from summit eruptions. Photo by Sergey Senyukov, KEMSD.

The current phase of unrest began with increasing seismicity below the volcano in mid-April, 1995, culminating in an explosive eruption that began on January 1, 1996, simultaneously at Karymsky volcano and from a vent at the north part of Karymsky Lake, about 10 km (6 mi) distant (Belousov and Belousov, 2000). For the remainder of 1996, periods of explosive eruptions of ash and small blocks alternated with periods of lava flow production (Neal and McGimsey, 1997). The eruption continued through 1998 and 1999 with intermittent explosions of gas and steam and occasionally ash (McGimsey and Wallace, 1999). Karymsky usually issues a continuous steam plume and is the most active volcano on the Kamchatkan Peninsula (Simkin and Siebert, 1994). Explosive and effusive-explosive eruptions of andesitic tephra and lava flows alternating with periods of repose are typical of Karymsky (Ivanov and others, 1991).

AVACHINSKY VOLCANO
CAVW #1000-10
53°15’ N 158°50’ E
2,751 m (8,890 ft)
Kamchatka Peninsula, Russia

Brief period of increased seismicity. Phreatic explosion on October 5, fracturing of summit lava complex, accompanied by intense fumarolic plume.

Seismicity was at background levels for the first eight months of 2001. In early September, while still at color code GREEN, KVERT began reporting an increasing number of earthquakes beneath the volcanic edifice. A fumarolic plume apparently became more consistently visible according to their weekly reports, and a thermal anomaly was spotted on September 22.

On October 5, an earthquake at 07:50 local time (KDT) within the edifice of Avachinsky accompanied by a small steam and ash explosion from the summit area. The explosion produced a dilute ash cloud that rose less than 1 km (~3300 ft) above the summit; ash fall was visible on the southeast sector of the cone. KVERT responded by declaring Level of Concern Color Code YELLOW. Following the explosion, small mudflows extending downslope from the summit area were visible to residents of a nearby settlement. Over the next few days, seismicity returned to roughly background levels, with a few exceptions. A thermal anomaly visible in satellite imagery appeared to outline the summit crater rim and the center of the crater on October 2. An intermittent, robust fumarolic plume emanating from the summit lava complex and was traceable up to 10 -20 km (~6–12 mi) downwind.

On October 17, KVERT was able to make observations from a helicopter overflight of Avachinsky. A new fracture cut ESE-WNW across a rubbly lava flow that had filled a pre-existing summit crater during the 1991 eruption and extended another 100-150 m (~330-500 ft) down the flank of the cone (fig. 26). Significant fumarolic activity and sulfur deposition was noted at the intersections of the fracture and the edifice. Although a powerful fumarolic plume persisted over the volcano at times, seismicity returned to normal and KVERT reverted to color code GREEN on November 2.

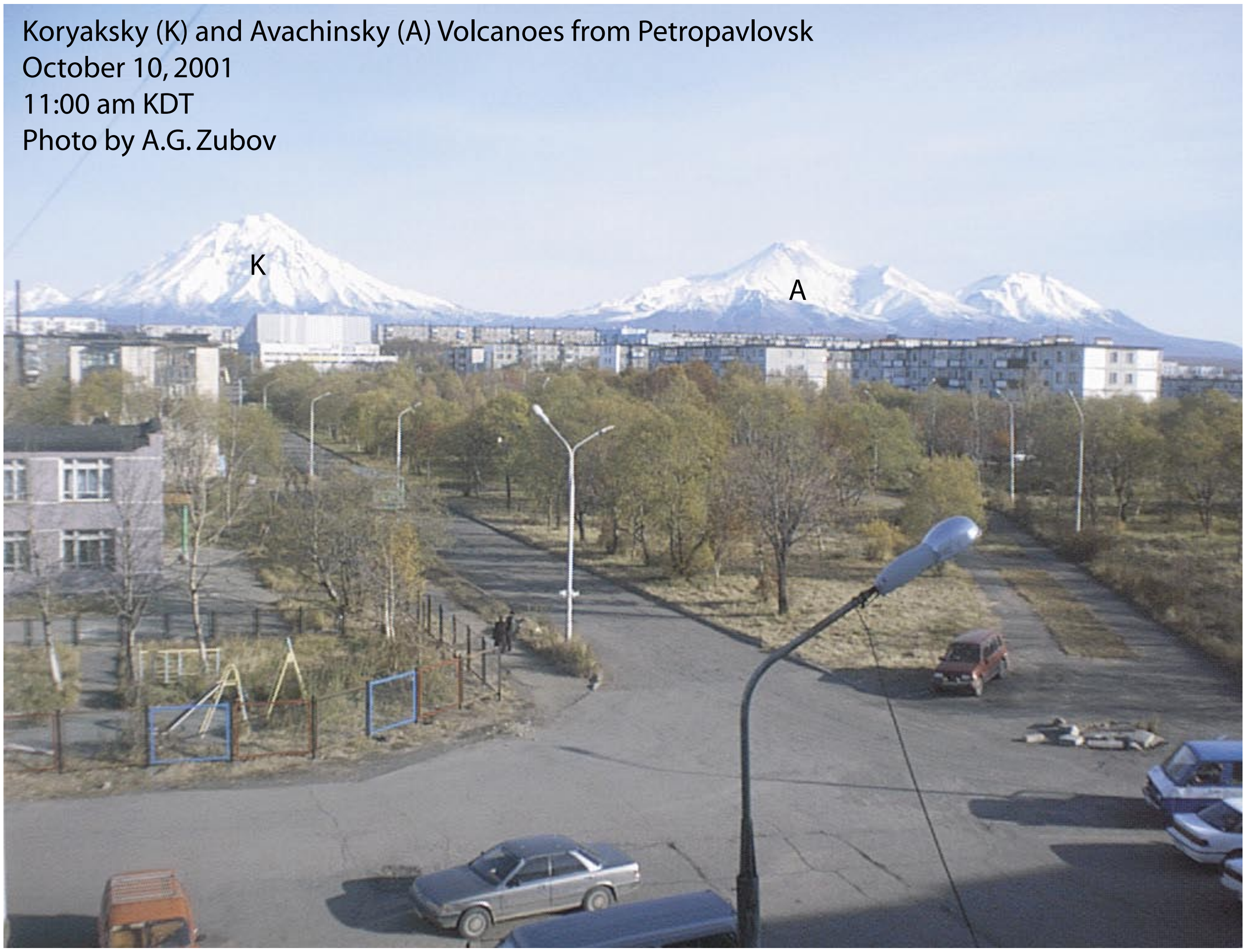


Figure 26. Koryaksky and Avachinsky Volcanoes as viewed from the KVERT office in Petropavlovsk-Kamchatsky on October 10, 2001. Photograph by A.G. Zubov, IVGG.

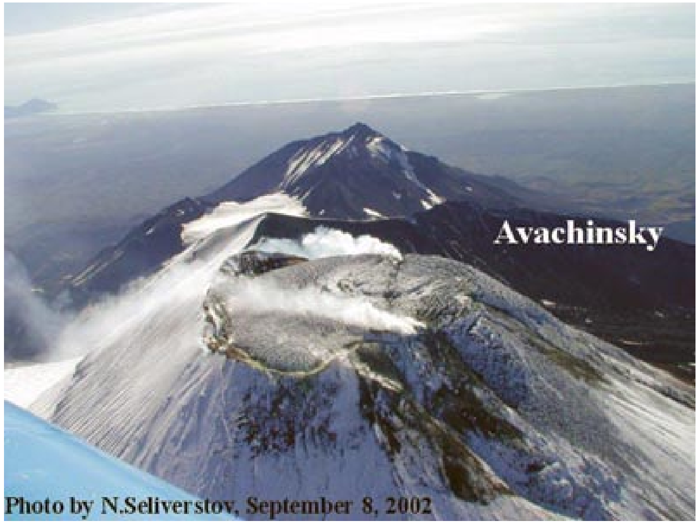


Figure 27. Oblique aerial view to the southeast over the summit of Avachinsky Volcano. The 1991 lava flow fills the summit crater and spills over the south-southwest rim. The 2001 fracture , steaming profusely at both ends, cuts across the surface of the 1991 lava flow. Photo by N. Seliverstov, September 8, 2002.

Avachinsky Volcano is the volcano nearest Petropavlovsk-Kamchatsky, the largest city in Kamchatka (population about 200,000 and the home of KVERT and its constituent Institutions). The snow-clad volcano looms only 25 km (15 mi) behind the city and frequently emits a white steam plume above its summit (fig. 27). Its last eruption was in 1991 and consisted of several explosions that dusted Petropavlovsk-Kamchatsky with several millimeters of ash, followed by a period of lava flow production and further explosions. Fumarolic activity in the summit area reflects magmatic degassing; temperatures as high as 473° C were measured in 1993-94 (Taran and others, 1999.) Avachinsky and its neighbor Koryaksky are monitored by a network of five short period seismic stations.

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ACKNOWLEDGMENTS

We thank Dave Schneider and Scott Stihler for reviewing this report; Steve Smith, Andrea Steffke, and Courtney Kearney for help with Kamchatka images; IVGG, KEMSD, KVERT members; and Christy Severtson for help with many of the Alaskan images, final formatting, and assembly of the report.

Table 1. Summary of 2001 VOLCANIC ACTIVITY in Alaska, including actual eruptions, possible eruptions, and unusual increases in fumarolic activity. Location of volcanoes shown in Figure 1.

Volcano	Date of Activity	Type of Activity
Shishaldin Volcano	Early June 2001 through end of November 2001	Increase in seismicity and steam clouds reported
Mt. Cleveland volcano	Early February to early May 2001	Eruptions: February 19, May 11, and May 19; disrupts NOPAC air traffic; lava flow reaches the sea

Table 2. Summary of SUSPECT VOLCANIC ACTIVITY (SVA) in 2001. SVA is defined as a report of eruption or possible eruption that is found to be normal fumarolic activity or non-volcanic phenomena, such as weather related. Location of volcanoes shown in Figure 1.

Volcano	Date of Activity	Type of Activity
Katmai Group: Snowy/Kukak	June 27, 2001; late summer 2001	Pilot reports of steaming hole in glacier on Snowy; steaming vernts on Kukak
Pavlof Volcano	January 20, 2001; early June 2001; November 7, 2001; December 13, 2001	Reports of steaming, possible ash; smell of sulfur
Frosty volcano	July 8, 2001; August 28, 2001	Low-snow summer, likely solar heating or orographic effects, and possible rock avalanches mistaken for eruptive activity
Makushin	February 22, 2001 through the Fall of 2001	Slight increase in number of small earthquakes
Great Sitkin	Early Februay through August 2001	Anomalous seismicity

Table 3. Summary of VOLCANIC ACTIVITY on Kamchatka Peninsula, Russia, 2001. Location of volcanoes shown in Figure 20.

Volcano	Date of Activity	Type of Activity
Sheveluch	Intermittently throughout the year. Significant explosive events on May 19, 21 and September 30.	Lava dome growth, short-lived, explosive episodes send ash as high as 11,5 km m (~66,000 ft) ASL, pyroclastic flows, localized ash fall.
Klyuchevskoy	Intermittently throughout the year	Elevated seismicity in March, April, November. Fumarolic plumes drift up to 100 km (62 mi) downwind.
Bezymianny	Intermittently throughout the year. Significant explosive event August 7.	Periods of increased seismicity, accelerated lava dome growth, explosions, ash plumes, pyroclastic flows and avalanches.
Karymsky	Significant explosion inferred from seismicity on November 16.	Periods of increased seismicity continuation of low-level vulcanian and strombolian explosions, avalanches, degassing.
Avachinsky	October 5	Phreatic explosion and short-lived ash plume 1 km (~3300 ft) over the summit, localized ash fall and mudflows, vigorous degassing.

Table 4. Level of Concern Color Code for volcanic activity.

LEVEL OF CONCERN COLOR CODE

To more concisely describe our level of concern about possible or ongoing eruptive activity at an Alaskan volcano, the Alaska Volcano Observatory uses the following color-coded classification system. Definitions of the colors reflect AVO's interpretations of the behavior of the volcano. Definitions are listed below followed by general description of typical activity associated with each color.

GREEN	**No eruption anticipated.** Volcano is in quiet, "dormant" state.
YELLOW	**An eruption is possible in the next few weeks and may occur with little or no additional warning.** Small earthquakes detected locally and (or) increased levels of volcanic gas emissions.
ORANGE	**Explosive eruption is possible within a few days and may occur with little or no warning. Ash plume(s) not expected to reach 25,000 feet above sea level.** Increased numbers of local earthquakes. Extrusion of a lava dome or lava flows (non-explosive eruption) may be occurring.
RED	**Major explosive eruption expected within 24 hours. Large ash plume(s) expected to reach at least 25,000 feet above sea level.** Strong earthquake activity detected even at distant monitoring stations. Explosive eruption may be in progress.

FOR PHOTOGRAPHIC IMAGES OF VOLCANOES IN THIS REPORT

Duplicate 35-mm slides and prints of some volcanoes discussed in this report are available from:
The Photo Library
U.S. Geological Survey
MS 914 Box 25046 Federal Center
Denver, CO 80225-0046
303-236-1010

Also, for digital images of Alaskan and Russian volcanoes, please see the following web sites:
http://www.avo.alaska.edu
http://volcanoes.usgs.gov/
http://www.volcano.si.edu/gvp/

PHOTOGRAPHS OF THE 1989-90 ERUPTIONS OF REDOUBT VOLCANO, ALASKA, USGS Open-file Report 96-689, 20 slides, 10 p. text and glossary, by A.L. Roach, C.A. Neal, and R.G. McGimsey.

PHOTOGRAPHS OF THE 1992 ERUPTIONS OF CRATER PEAK, SPURR VOLCANO, ALASKA, USGS Open-file Report 93-707, 20 slides, 8 p. text and glossary, by Christina A. Neal, Robert G. McGimsey, Michael P. Doukas, and Inyo Ellerseick, 1993. 20-slide set illustrating aspects of the 1992 eruptions. Includes captions and glossary.

VOLCANOES OF THE WRANGELL MOUNTAINS AND COOK INLET REGION, ALASKA - SELECTED PHOTOGRAPHS, U.S. Geological Survey, Digital Data Series 96-039, 1996, CD-ROM. Also available for download via the internet: http://wrgis.wr.usgs.gov/dds/dds-39/

VOLCANOES OF THE ALASKA PENINSULA AND ALEUTIAN ISLANDS, ALASKA - SELECTED PHOTOGRAPHS, U.S. Geological Survey, Digital Data Series 96-040, 1996, CD-ROM. Also available for download via the internet: http://wrgis.wr.usgs.gov/dds/dds-40/

The publications listed above are available from:

U.S. Geological Survey ESIC-Open-File Report Section
Box 25286, MS 517
Denver, CO 80225-0046
303-236-7476

GLOSSARY OF SELECTED TERMS

a'a:
an Hawaiian term for lava flows characterized by a rough, jagged, blocky surface, typically difficult to walk upon

ADT:
"Alaska Daylight Time"

AEIC:
"Alaska Earthquake Information Center"

ASL:
"above sea level"

AVO:
"Alaska Volcano Observatory"

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

andesite:
volcanic rock composed of about 53 to 63 percent silica (SiO2, 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

basalt:
general term for dark-colored igneous rock, usually extrusive, containing about 45 to 52 weight percent silica (SiO2, an essential constituent of most minerals found in rocks)

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

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

CAVW:
Smithsonian Institute's "Catalog of Active Volcanoes of the World"

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

COSPEC:
"Correlation Spectrometer"; device for measuring sulfur dioxide emissions

FAA:
"Federal Aviation Administration"

fallout:
a general term for debris which falls to the earth from an eruption cloud

fault:
a fracture or zone of fractures along which there has been displacement of the sides relative to one another

FIR:
"Flight Information Region"

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

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

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

glaciolacustrine:
pertaining to sediments deposited in glacial lakes, and resulting landforms

GMS:
"Geostationary Meteorological Satellite"

GVN:
"Global Volcanism Network"

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

incandescent:
glowing red or orange due to high temperature

intracaldera:
refers to something within the caldera

IVGG:
Russian “Institute of Volcanic Geology and Geochemistry”

JMA:
“Japanese Meteorological Agency”

Ka:
Thousands of years before the present

KDT:
“Kamchatkan Daylight Time”, which = ADT + 21 hrs.

KEMSD:
Russian “Kamchatka Experimental and Methodical Seismology Department”

KVERT:
Russian “Kamchatkan Volcano Eruption Response Team”

lapilli:
pyroclasts that are between 2 and 64 mm in diameter

lava:
when molten material reaches the earth’s surface, it is called lava

magma:
molten material below the surface of the earth

NOAA:
“National Oceanic and Atmospheric Administration”

NOPAC:
“North Pacific Air Corridor”

NOTAM:
“Notice to Airmen”, a notice containing information [not known sufficiently in advance to publicize by other means] concerning the establishment, condition, or change in any component [facility, service, or procedure of, or hazard in the National Airspace System] the timely knowledge of which is essential to personnel concerned with flight operations

NWS:
“National Weather Service”

phreatic activity:
an explosive eruption caused by the sudden heating of ground water as it comes in contact with hot volcanic rock or magma

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

PIREP:
“Pilot Weather Report - A report of meteorological phenomena encountered by aircraft in flight

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

Pleistocene:
geologic epoch extending from 2-3 million years ago to approximately 10,000 years before present

pumice-rich lapilli:
particles ejected during a volcanic eruption that are composed mostly of pumice and between 2 and 64 mm in size

pyroclast:
an individual particale ejected during a volcanic eruption; usually classified by size, e.g. ash, lapilli

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

RFE:
“Russian Far East”

SAB:
“Synoptic Analysis Branch” of NOAA

SAR:
“Synthetic Aperture Radar”

satellite cone:
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

shield volcano:
a broad, gently sloping volcano usually composed of fluid, lava flows of basalt composition (e.g. Mauna Loa, Hawaii)

SIGMET:
“Significant Meteorological information statement”, issued by NWS

stratovolcano:
(also called a stratocone or composite cone) a steep-sided volcano, usually conical in shape, built of interbedded lava flows and fragmental deposits from explosive eruptions

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

subplinian:
style of explosive eruptions characterized by vertical eruption columns and widespread dispersal of tephra

SVA:
“suspect volcanic activity”

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

TFR:
“Temporary Flight Restriction”, issued by FAA

USCG:
“United States Coast Guard”

USGS:
“United States Geological Survey”

UTC:
“Coordinated Universal Time”; same as Greenwich Mean Time (GMT)

VAAC:
“Volcanic Ash Advisory Center”

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

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

UAFGI:
"University of Alaska Fairbanks Geophysical Institute"