Report of Investigation 2026-5

The Alaska Volcano Observatory is a consortium between the U.S. Geological Survey, the University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological & Geophysical Surveys.

Volcanic Activity in Alaska and the Northern Mariana Islands in 2024—Summary of Events and Response of the Alaska Volcano Observatory

State of Alaska
Department of Natural Resources
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Cover. Oblique aerial photograph of the summit of Mount Spurr, looking southwest, showing a weak plume from the summit crater. Photograph by W. Mayo, U.S. Geological Survey, October 24, 2024.

Acknowledgments

This report represents the work of the entire Alaska Volcano Observatory staff, colleagues from other U.S. Geological Survey volcano observatories, and cooperating State and Federal agencies. We thank those members of the public who shared observations and photographs. This publication is published with funding provided under USGS Volcano Hazard Program/DGGS cooperative agreement G26AS00036.

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Conversion Factors

U.S. customary units to International System of Units:

Multiply	By	To Obtain
Length		
foot (ft)	0.3048	meter (m)
foot (ft)	0.000305	kilometer (km)

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
Area		
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
Volume		
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
Velocity		
meter per second (km/s)	3,281	foot per second (ft/s)
Mass flow		
metric ton per day (t/d)	1.1022	ton, long [2,240 lb] per day
metric ton per day (t/d)	0.9842	ton, short [2,000 lb] per day

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

$$°F = (1.8 \times °C) + 32.$$

Datum

Altitude, as used in this report, refers to distance above sea level of a location in the air.

Elevation, as used in this report, refers to distance above sea level of a location on the land surface.

Depth, as used in this report, refers to distance below sea level.

Locations in latitude and longitude are presented in decimal degrees referenced to the World Geodetic System 1984 (WGS84) datum, unless otherwise noted.

Abbreviations

AKDT	Alaska daylight time; UTC−8 hours
AKST	Alaska standard time; UTC−9 hours
ALOS-2	Advanced Land Observing Satellite-2
ASL	above sea level
AVO	Alaska Volcano Observatory
BSL	below sea level
ChST	Chamorro standard time; UTC +10 hours
CNMI	Commonwealth of the Northern Marianas Islands
CO2	carbon dioxide
DOAS	Differential Optical Absorption Spectroscopy
DLP	deep long-period
ESA	European Space Agency
GOES	Geostationary Operational Environmental Satellite
GNSS	Global Navigation Satellite System
GVP	Smithsonian Institution Global Volcanism Program
HADT	Hawaii-Aleutian daylight time; UTC−9 hours
HAST	Hawaii-Aleutian standard time; UTC−10 hours
H2O	water (including water vapor and ice)
InSAR	Interferometric Synthetic Aperture Radar
IR	infrared
LOS	line-of-sight
LP	long-period
MultiGAS	multi-component gas analyzer system
M/ML	magnitude/local magnitude
NEIC	National Earthquake Information Center
NMI	Northern Marianas Islands
NWS	National Weather Service
#	number
PDC	pyroclastic density current
PIREP	pilot weather report
RMS	root mean square
SO2	sulfur dioxide
SIGMET	Significant Meteorological Information notice
TROPOMI	the TROPOspheric Monitoring Instrument
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
UTC	coordinated universal time; same as Greenwich mean time
VAN/VONA	Volcanic Activity Notice/Volcano Observatory Notice for Aviation
VIIRS	Visible Infrared Imaging Suite
VT	volcano-tectonic
WGS84	World Geodetic System 1984 datum

Volcanic Activity in Alaska and the Northern Mariana Islands in 2024—Summary of Events and Response of the Alaska Volcano Observatory

By Tim R. Orr,[1] Ronni Grapenthin,[2] David Fee,[2] Hannah R. Dietterich,[1] Aaron G. Wech,[1] Peter J. Kelly,[3] and Taryn M. Lopez[2]

Abstract

In 2024, the Alaska Volcano Observatory responded to eruptions, volcanic unrest or suspected unrest, increased seismicity, and other significant activity at 10 volcanic centers in Alaska and the Northern Mariana Islands. Eruptive activity in Alaska consisted of the eruption of a thick lava flow within the summit crater at Great Sitkin Volcano throughout the entire year and a small explosion at Atka volcano in March. Uplift, elevated seismicity, and the redevelopment of a summit meltwater lake was detected at Mount Spurr. A brief seismic swarm occurred at Mount Gareloi, while at Trident Volcano, Shishaldin Volcano, and Kanaga Volcano, seismicity declined to background levels, marking the end of unrest and volcanic activity for those volcanoes. Other activity that the Alaska Volcano Observatory responded to in 2024 included ash resuspension events at Mount Katmai, and a period of unrest at Mount Cleveland. Finally, at Ahyi seamount, in the Commonwealth of the Northern Marianas Islands, a plume of discolored ocean water observed in satellite data indicated underwater eruptive activity there.

Introduction

The Alaska Volcano Observatory (AVO) is a joint program of the U.S. Geological Survey (USGS); the University of Alaska Fairbanks, Geophysical Institute; and the Alaska Division of Geological & Geophysical Surveys. Formed in 1988, AVO uses Federal, State, and university resources to (1) monitor and study Alaska's hazardous volcanoes to assess the nature, timing, and likelihood of volcanic activity; (2) assess volcanic hazards associated with anticipated activity, including the kinds of events, their effects, and areas at risk; and (3) provide timely and accurate information on volcanic hazards, and warnings of impending dangerous activity, to officials (local, State, and Federal) and the public, including the aviation sector. AVO also monitors the volcanoes in the Commonwealth of the Northern Mariana Islands (fig. 1).

The AVO volcano monitoring program involves daily analyses of satellite and webcam imagery, seismicity, and infrasound detections; occasional overflights and ground visits; airborne and ground-based gas measurements; and the compilation of visual observations taken from observatory personnel, resident and mariner accounts, and from pilot weather reports (PIREPs; reports of meteorological phenomena encountered by aircraft in flight). AVO also monitors volcano ground deformation using real-time data from permanent Global Navigation Satellite System (GNSS) stations and Interferometric Synthetic Aperture Radar (InSAR) imagery.

With this information, AVO assigns each monitored volcano an Aviation Color Code and Volcano Alert Level, which indicate its current activity status (Gardner and Guffanti, 2006). No assignment is given to volcanoes that lack local seismic monitoring and appear to be at background level. However, these seismically unmonitored volcanoes are given an Aviation Color Code and Volcano Alert Level if regional seismic networks or other monitoring streams (for instance, satellite monitoring) indicate ongoing activity or elevated unrest. The Aviation Color

[1]U.S. Geological Survey Alaska Volcano Observatory
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[3]U.S. Geological Survey Cascades Volcano Observatory

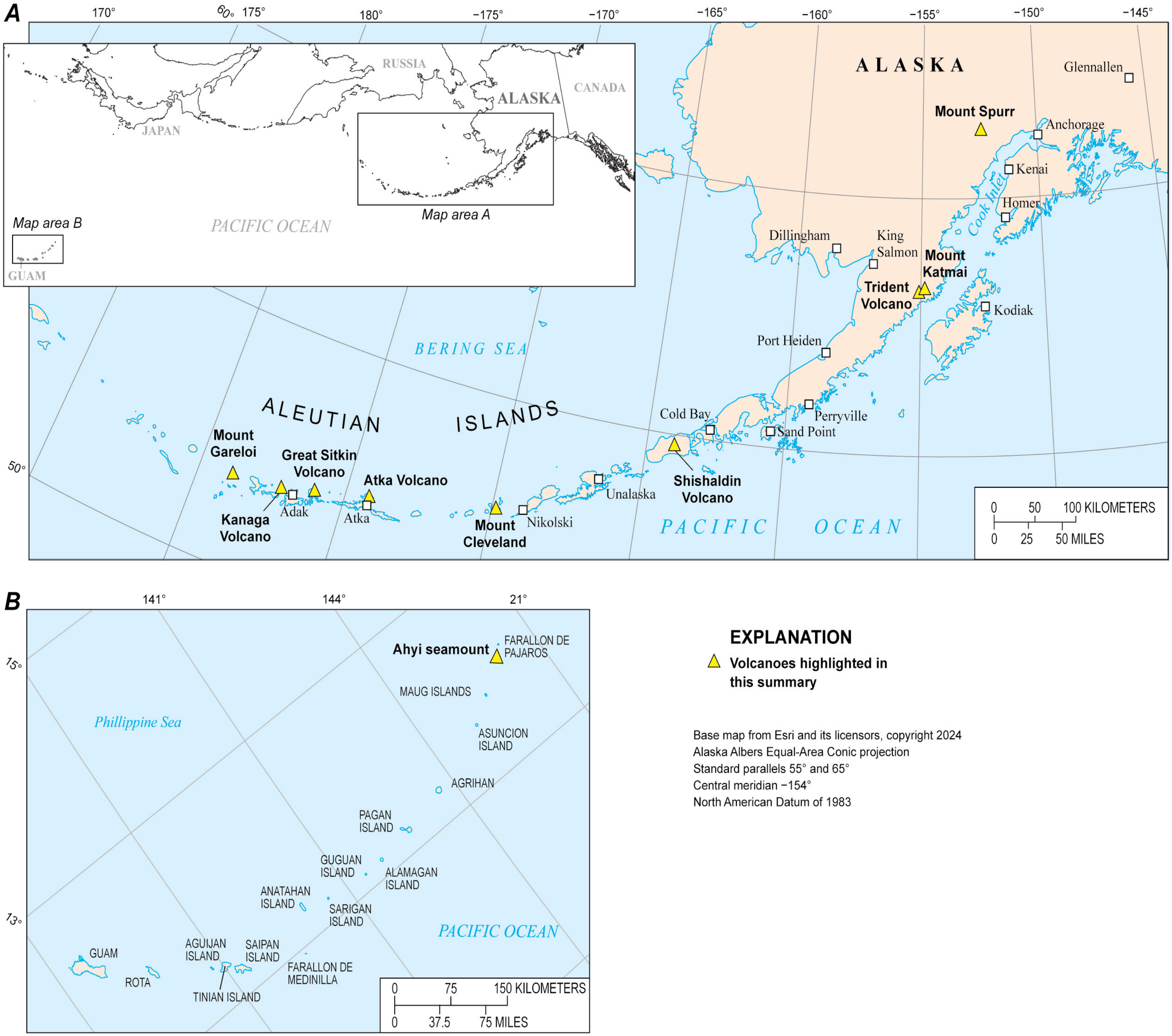

Figure 1. Map of Alaska (A) and Commonwealth of the Northern Mariana Islands (B) volcanoes highlighted in this summary.

Code addresses the hazards to aviation posed by a volcano, whereas the Volcano Alert Level addresses the hazards on the ground. Although the Aviation Color Code and Volcano Alert Level are usually changed together, there could be situations where they are changed independently. For instance, a volcano might produce lava flows that are dangerous on the ground, which would require a Volcano Alert Level of **WARNING**, but the hazard to aviation would be minimal, meriting an Aviation Color Code of **ORANGE**. Where possible, Volcano Alert Level announcements contain additional explanations of volcanic activity and expected hazards. Table 1 and table 2 define each Aviation Color Code and Volcano Alert Level.

AVO duty scientists are responsible for compiling all monitoring data to provide scheduled and event-driven public notices, as appropriate. Some AVO scientists also participate in a weekly remote-sensing rotation, during which time they produce daily reports summarizing satellite and webcam observations at volcanoes with elevated Aviation Color Codes and Volcano Alert Levels. The reports also describe any

Table 1. Definitions of the Aviation Color Codes used by United States volcano observatories.

Aviation Color Code	Definition
GREEN	Volcano is in typical background, noneruptive state or, after a change from a higher level, volcanic activity has ceased, and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level or, after a change from a higher level, volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, or eruption is underway with no or minor volcanic-ash emissions [ash-plume height specified, if possible].
RED	Eruption is imminent with significant emission of volcanic ash into the atmosphere likely, or eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible].
UNASSIGNED	Ground-based instrumentation is insufficient to establish that volcano is at typical background level (GREEN/NORMAL). When activity at such a volcano increases to the point of being detected by remote sensing instruments, distant seismic networks, or eyewitness reports, an alert level and color code are assigned accordingly. When activity decreases, volcano goes back to UNASSIGNED without going through GREEN/NORMAL.

Table 2. Definitions of the Volcano Alert Levels used by United States volcano observatories.

Volcano Alert Level	Definition
NORMAL	Volcano is in typical background, noneruptive state or, after a change from a higher level, volcanic activity has ceased, and volcano has returned to noneruptive background state.
ADVISORY	Volcano is exhibiting signs of elevated unrest above known background level or, after a change from a higher level, volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
WATCH	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain, or eruption is underway but poses limited hazards.
WARNING	Highly hazardous eruption is imminent, underway, or suspected.
UNASSIGNED	Ground-based instrumentation is insufficient to establish that volcano is at typical background level (GREEN/NORMAL). When activity at such a volcano increases to the point of being detected by remote sensing instruments, distant seismic networks, or eyewitness reports, an alert level and color code are assigned accordingly. When activity decreases, volcano goes back to UNASSIGNED without going through GREEN/NORMAL.

notable observations at other volcanoes that AVO monitors. All observations are archived in a relational database. Other AVO scientists and scientists from the USGS National Earthquake Information Center monitor volcano seismicity and infrasound using local and regional sensors. This team compiles three separate seismic reports daily, spaced ~8 hours apart. Like the daily remote sensing reports, the seismic reports are catalogued in a relational database. Many AVO scientists fill two of these roles simultaneously. Coombs and others (2024) provide a detailed look at how AVO monitors volcanoes in Alaska.

Purpose and Scope

This report summarizes eruptive activity and other notable unrest associated with volcanoes in Alaska and the Commonwealth of the Northern Mariana Islands during 2024 (fig. 1, table 3, table 4) and briefly describes AVO's response. It contains information about all identified volcanic unrest, even if no formal public notification was issued at the time. Observations, images, and information that are typically not published elsewhere are included in this report. Similar annual summaries of volcanic unrest and AVO's response have been published since 1992 (https://avo.alaska.edu/explore/search/annual-summaries).

The volcanoes in this report are presented in geographic order from east to west along the Aleutian arc, and afterward the volcanoes of the Commonwealth of the Northern Mariana Islands are presented from north to south. Each entry has a title block containing information about that volcano: its identifier number (#) assigned by the Smithsonian Institution Global Volcanism Program (GVP); its latitude, longitude, and summit elevation; the name of its geographic region; and an abbreviated summary of its 2024 activity. The title block is followed by a description of the volcano and a summary of its past activity, then a detailed account of its activity during the year, often with accompanying tables, images, figures, or all three. This information is derived from formal public AVO information products, internal online electronic logs compiled by AVO staff, and published material.

AVO sometimes uses informal volcano names for clarity; the names provided by the official U.S. Board on Geographic Names (through the Geographic Names Information System) may match poorly with the volcanoes themselves. For example, Bogoslof volcano comprises more islands than Bogoslof Island. Alaska also has volcanoes without official place names, such as Takawangha volcano, which necessitates the use of informal names.

In this report, date references are given in coordinated universal time (UTC). Measurements are presented in the International System of Units, except for altitudes, which are reported in feet above sea level (ASL), in line with federal aviation

Table 3. Summary of activity at Alaska and Northern Mariana Islands volcanoes in 2024, including but not limited to confirmed eruptions, possible eruptions, increases in seismicity, observations of fumarolic activity, and other notable events.

[Volcanoes presented in geographic order from east to west in Alaska, and north to south in the Commonwealth of Northern Mariana Islands. Volcano locations shown in Figure 1.]

Volcano	Type of activity
Mount Spurr	Ground deformation, elevated seismicity, summit melting, and formation of a meltwater lake
Mount Katmai	Resuspension of 1912 ash
Trident Volcano	Waning seismicity following 2022–2023 intrusive activity
Shishaldin Volcano	Waning seismicity following 2023 explosive eruption
Mount Cleveland	Elevated surface temperatures, gas emissions
Atka volcano (Korovin Volcano)	Small explosion
Great Sitkin Volcano	Ongoing eruption of lava flow
Kanaga Volcano	Waning seismicity following phreatic eruption in 2023
Mount Gareloi	Earthquake swarm
Ahyi seamount	Submarine eruption

Table 4. Aviation Color Code and Volcano Alert Level changes during 2024 at volcanoes in Alaska and the Commonwealth of the Northern Mariana Islands discussed in this report.

[Volcanoes presented in geographic order from east to west along the Aleutian arc, and north to south in the Commonwealth of Northern Mariana Islands. See Table 1 and Table 2 for definitions of Aviation Color Codes and Volcano Alert Levels.]

Aviation Color Code/Volcano Alter Level	Date and time of change	
	UTC	local
	Mount Spurr	
GREEN/NORMAL	Beginning of year	
UNASSIGNED	February 16, 2024, 20:44 UTC	February 16, 2024, 11:44 AM AKST
GREEN/NORMAL	April 5, 2024, 00:30 UTC	April 4, 2024, 4:30 PM AKDT
YELLOW/ADVISORY	October 16, 2024, 20:07 UTC	October 16, 2024, 12:07 PM AKDT
	Mount Katmai (Novarupta)	
GREEN/NORMAL	No change entire year	
	Trident Volcano	
YELLOW/ADVISORY	Beginning of year	
GREEN/NORMAL	January 10, 2024, 20:04 UTC	January 10, 2024, 11:04 AM AKST
	Shishaldin Volcano	
ORANGE/WATCH	Beginning of year	
YELLOW/ADVISORY	January 2, 2024, 20:33 UTC	January 2, 2024, 11:33 AM AKST
ORANGE/WATCH	February 11, 2024, 21:46 UTC	February 11, 2024, 12:46 PM AKST
YELLOW/ADVISORY	February 17, 2024, 20:26 UTC	February 17, 2024, 11:26 AM AKST
GREEN/NORMAL	August 30, 2024, 17:00 UTC	August 30, 2024, 9:00 AM AKDT
	Mount Cleveland	
GREEN/NORMAL	Beginning of year	
YELLOW/ADVISORY	July 5, 2024, 22:54 UTC	March 27, 2024, 8:06 PM HADT
GREEN/NORMAL	July 8, 2024, 20:54 UTC	July 8, 2024, 11:54 AM HADT
	Atka volcano (Korovin Volcano)	
GREEN/NORMAL	Beginning of year	
YELLOW/ADVISORY	March 28, 2024, 05:06 UTC	July 5, 2024, 1:54 PM HADT
GREEN/NORMAL	April 9, 2024, 15:34 UTC	April 9, 2024, 6:34 AM HADT
	Great Sitkin Volcano	
ORANGE/WATCH	No change entire year	

	Kanaga Volcano	
YELLOW/ADVISORY	Beginning of year	
GREEN/NORMAL	February 27, 2024, 20:10 UTC	February 27, 2024, 10:10 AM HAST
	Mount Gareloi	
GREEN/NORMAL	Beginning of year	
YELLOW/ADVISORY	February 12, 2024, 22:10 UTC	February 12, 2024, 12:10 PM HAST
GREEN/NORMAL	March 5, 2024, 20:50 UTC	March 5, 2024, 10:50 AM HAST
	Ahyi Seamount	
UNASSIGNED	Beginning of year	
YELLOW/ADVISORY	January 13, 2024, 22:50 UTC	January 14, 2024, 8:50 AM ChST
UNASSIGNED	April 9, 2024, 17:46 UTC	April 10, 2024, 3:46 AM ChST
YELLOW/ADVISORY	November 19, 2024, 23:43 UTC	November 20, 2024, 9:43 AM ChST

standards, followed by meters (m) in parentheses. Earthquake depths are modeled in relation to the World Geodetic System of 1984 (WGS84), and the accuracy of depth given relates directly to how many stations were used to record the event (that is, accuracy of depth decreases with fewer recording stations). Volcano locations (in decimal degrees latitude and longitude) are taken from AVO's database of Alaska volcanoes (Cameron and others, 2022), and their summit elevations are derived from the 2019 IfSAR data for the State of Alaska (U.S. Geological Survey, 2019; https://elevation.alaska.gov/). These elevations may differ from past AVO annual summaries, which were derived from less accurate sources. The depth of Ahyi seamount below sea level comes from Tepp and others (2019).

What is an "Eruption"?

The specific use of the term "eruption" varies from scientist to scientist and has no universally agreed-upon definition. Here, we adopt the usage of Siebert and others (2010, p. 17), who define eruptions as "…events that involve the explosive ejection of fragmental material, the effusion of liquid lava, or both." The critical elements of this definition are the verbs "ejection" and "effusion," which refer to dynamic surface processes that pose some level of hazard. The presence or absence of "juvenile material," or newly erupted rock, which can sometimes be ambiguous, is not relevant to this use of the term eruption, particularly when communicating a potential hazard. This definition does not, however, include passive volcanic degassing or hydrothermal fluid discharge.

What is a "Historically Active Volcano"?

AVO defines an active volcano as a volcanic center that has recently had an eruption (see "What is an 'Eruption' ") or a period of intense deformation, seismic activity, or fumarolic activity; these are inferred to reflect the presence of magma at shallow levels beneath the volcano. AVO considers the historical period in Alaska to be since 1741 (about the past 280 years), when written records of volcanic activity began. Based on a rigorous reanalysis of all volcanic activity accounts in Alaska (from many sources), Cameron and others (2023) concluded that 54 Alaska volcanoes fit these criteria, but we modify the number in this report to 53, since we consider Novarupta to be a subfeature of Mount Katmai (Hildreth and Fierstein, 2000). As geologic understanding of Alaska volcanoes improves through additional fieldwork and modern radiometric dating techniques, our list of active volcanoes will continue to evolve.

Volcanic Activity in Alaska

Mount Spurr

GVP# 313040
61.299°, –152.254°
3,376 m
Cook Inlet

GROUND DEFORMATION, ELEVATED SEISMICITY, SUMMIT MELTING AND FORMATION OF A MELTWATER LAKE

Mount Spurr is a 3,376-meter-high, ice- and snow-covered stratovolcano located ~125 km west of Anchorage (fig. 1; https://avo.alaska.edu/volcano/spurr). Its largely ice-covered summit cone (fig. 2) might be a slightly altered lava dome complex (Nye and Turner, 1990), and its last known eruption prior to historical times, calculated by correlating tephra deposits, took place ~5,200 years ago (Riehle, 1985). Although the summit of Mount Spurr has not erupted recently, Crater Peak, a satellite vent 3.5 km south of the summit (fig. 2), produced one explosive eruption in 1953 and three in 1992 (Keith, 1995, and references therein). All eruptive activity led to ashfalls that impacted populated areas in south-central Alaska. More recently, in 2004–2006, Mount Spurr experienced a period of unrest interpreted to be the result of new magma injecting to a shallow level beneath the volcano (fig. 3; Power, 2004; Power and others, 2004). This unrest was marked by elevated seismicity, magmatic gas emissions, the generation of water-rich debris flows, and increased heat flux, the last of which formed a melt pit and crater lake at the volcano's summit (Neal and others, 2005; Coombs and others, 2006; McGimsey and others, 2008; Neal and others, 2009).

On April 25–26, 2024, a seismic swarm consisting of 33 events occurred at Mount Spurr. This followed a period of above-background seismicity (~4 events/day) observed earlier in the month. With this increase, the volcano

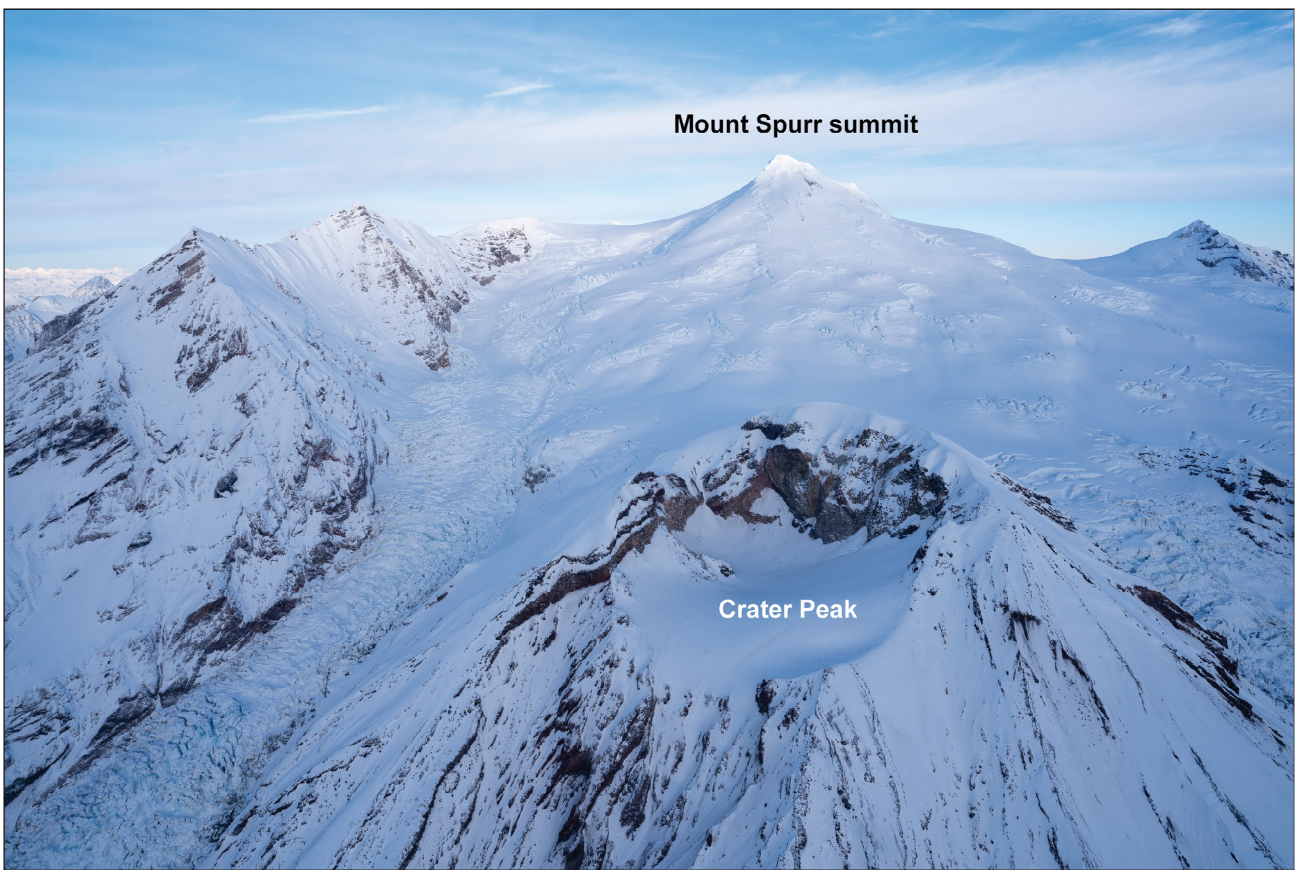

Figure 2. Oblique aerial photograph of Mount Spurr and its flank vent, Crater Peak, looking north-northwest, on October 24, 2024. Photograph by W. Mayo, U.S. Geological Survey.

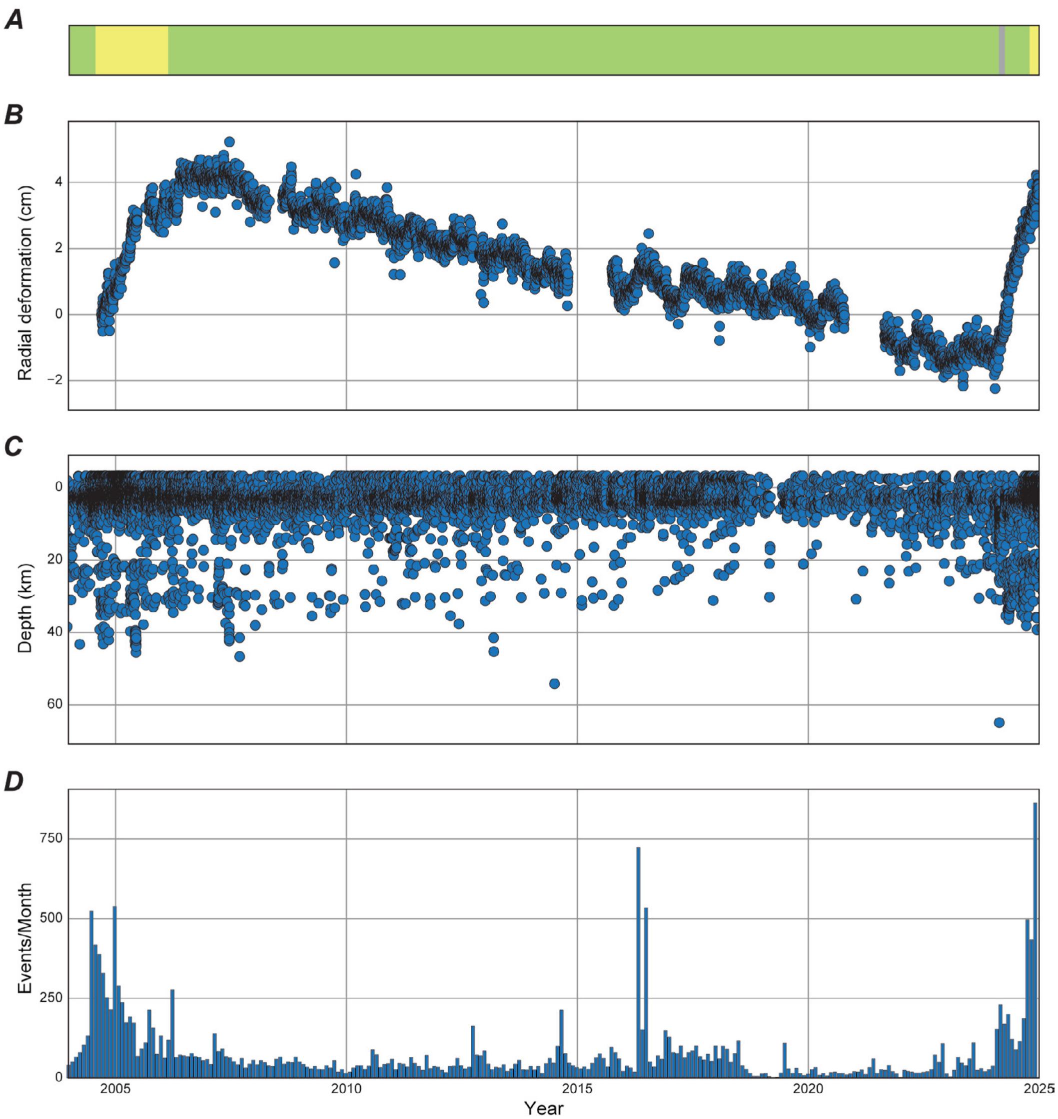

Figure 3. Mount Spurr timeline from 2004 to 2025 showing (A) Aviation Color Code and Volcano Alert Level (green is GREEN/NORMAL, yellow is YELLOW/ADVISORY, gray is UNASSIGNED), (B) Global Navigation Satellite System station (GNSS) SPBG timeseries towards (negative) and away from (positive) Mount Spurr summit relative to base station AC59, (C) earthquake hypocenter depths, and (D) monthly earthquake count.

entered its first unrest phase since the 2004–2006 magmatic intrusion (fig. 3), although the actual onset date of the renewed seismic activity is uncertain due to a seismic network outage that lasted from mid-February to early April (table 4, fig 4). After a period of watchfulness, AVO issued an Information Statement on May 15, 2024, pointing out the occurrence of deep low-frequency earthquakes below 20 km depth (fig. 3, fig. 4, fig. 5) and noting new observations of about 1 cm of uplift recorded by GNSS station SPBG. Retrospective analysis determined that the deformation began in January or February 2024 (fig. 3 and fig. 4). A mix of shallow volcano-tectonic and shallow long-period earthquakes were also found to have occurred during this early period of deformation, prior to the seismic network outage (fig. 4).

The increased seismicity and deformation were a clear deviation from observations between 2006–2023, when earthquake counts were generally around 10–20 earthquakes per week, and the GNSS network recorded deflation (fig. 3). In addition, an increase in heat flow in early 2024 led to the formation of a melt pit and crater lake at the summit of the volcano (fig. 6), similar to

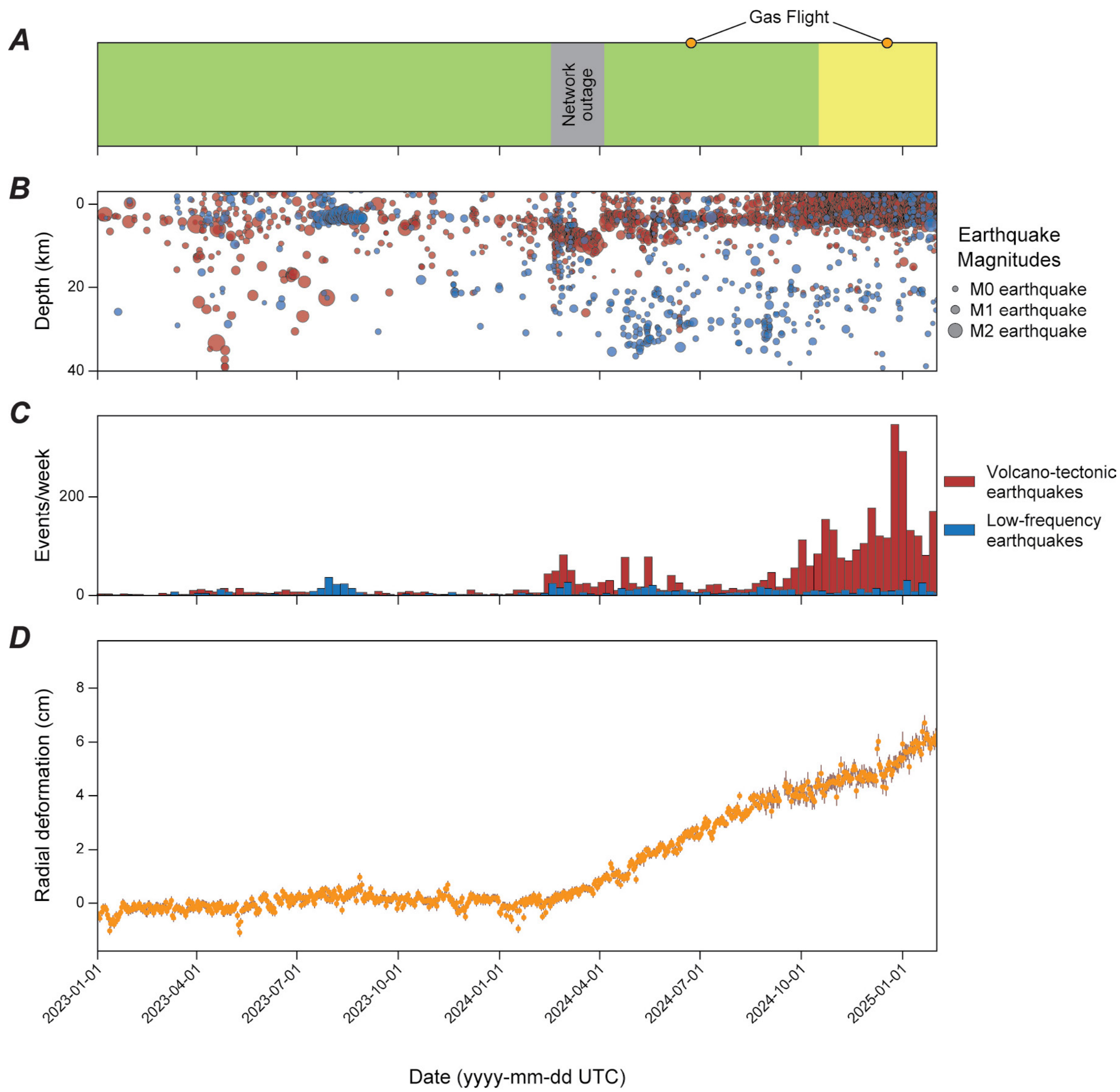

Figure 4. Mount Spurr timeline from January 2023 through January 2025 showing (A) Aviation Color Code and Volcano Alert Level (green is GREEN/NORMAL, yellow is YELLOW/ADVISORY, gray is UNASSIGNED), period of network outage, and gas flights; (B) earthquake depths, magnitudes, and (C) weekly earthquake count within a 25 km radius of Mount Spurr's summit, where red are volcano-tectonic earthquakes and blue are low-frequency earthquakes; and (D) motion of GNSS station SPBG, relative to AC59, away from the volcano. Cumulative outward motion is about 6 cm, or 2.4 inches. Dates are given in year-month-day format.

that which formed during the 2004–2006 unrest. The crater lake, which formed sometime between May 15 and June 15, grew over the following months. No evidence of increased heat flow was exhibited at Crater Peak.

Unrest at Mount Spurr persisted through the remainder of 2024. AVO closely monitored the activity—respective disciplinary observations are summarized below—and kept its stakeholders informed via two additional Information Statements, issued on July 3 and October 9. Existing ground-based geophysical monitoring was supplemented with two dedicated gas flights on June 23 and December 18 (fig. 4). AVO also conducted additional fieldwork on October 24 to ensure winter observations by hardening the instrument network. Substantial increases in seismicity in October (~900 events total) combined with continued inflation (up to 4 cm radial deformation) and the ongoing presence

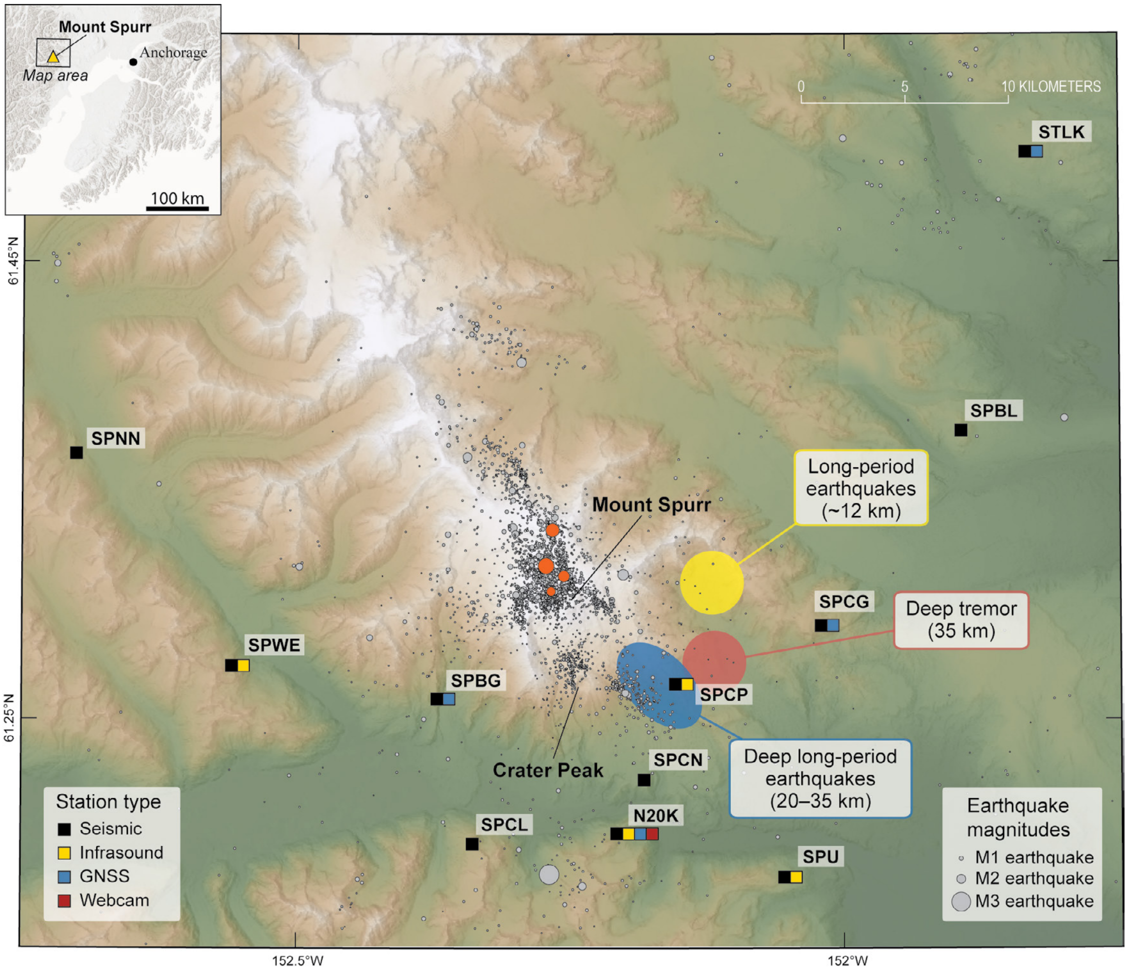

Figure 5. Map of the Mount Spurr area monitoring station locations and instrumentation, volcano-tectonic earthquakes (gray circles; orange circles mark four larger shallow volcano-tectonic earthquakes), and the locations of long-period earthquakes (orange polygon) and tremor (red polygon) compared to deep long-period earthquake locations (blue polygon) in 2024.

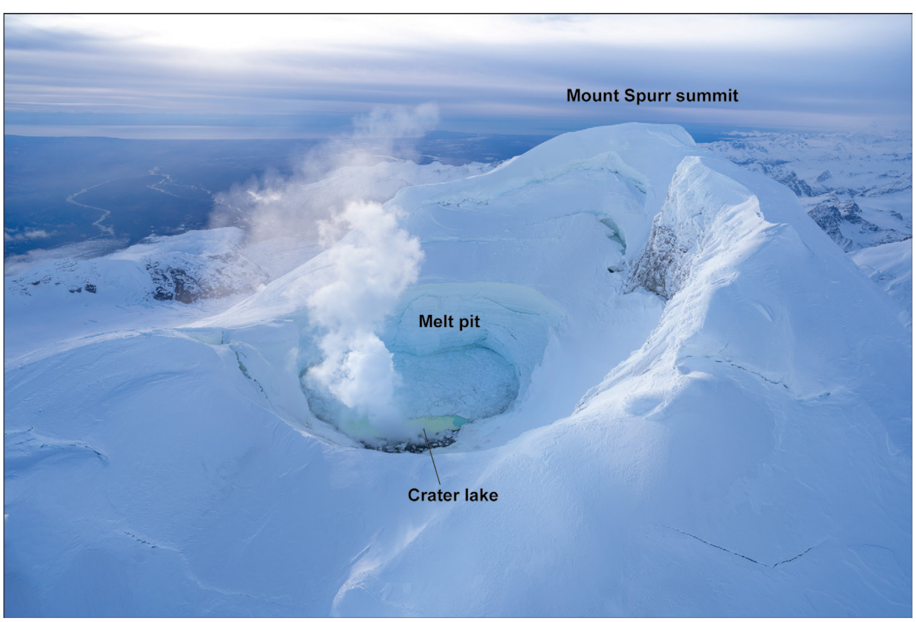

Figure 6. Oblique aerial photograph of the summit of Mount Spurr, looking southeast, showing the melt pit and crater lake that formed in response to increase heat flow during volcanic unrest in 2024. Photograph by W. Mayo, U.S. Geological Survey.

of the crater lake prompted AVO to increase the Aviation Color Code and Volcano Alert Level to **YELLOW** and **ADVISORY** on October 16, where it remained for the rest of the year (table 4).

Seismicity throughout the year consisted broadly of shallow (<10 km) volcano-tectonic earthquakes and deep (>20 km) low-frequency activity, with relatively few earthquakes between 10–20 km. Some shallow (<10 km) low-frequency events accompanied the entire sequence in 2024 (fig. 4). Earthquake counts were at about 30 per week from April through the end of May, although a few weeks exceeded this number. Thereafter, until the end of September, the weekly counts remained substantially below these early peaks. The number of events per week then increased to around 100 from October to December and increased again to more than 300 events per week in late December (fig. 4). Notably, several low-frequency earthquakes (generally

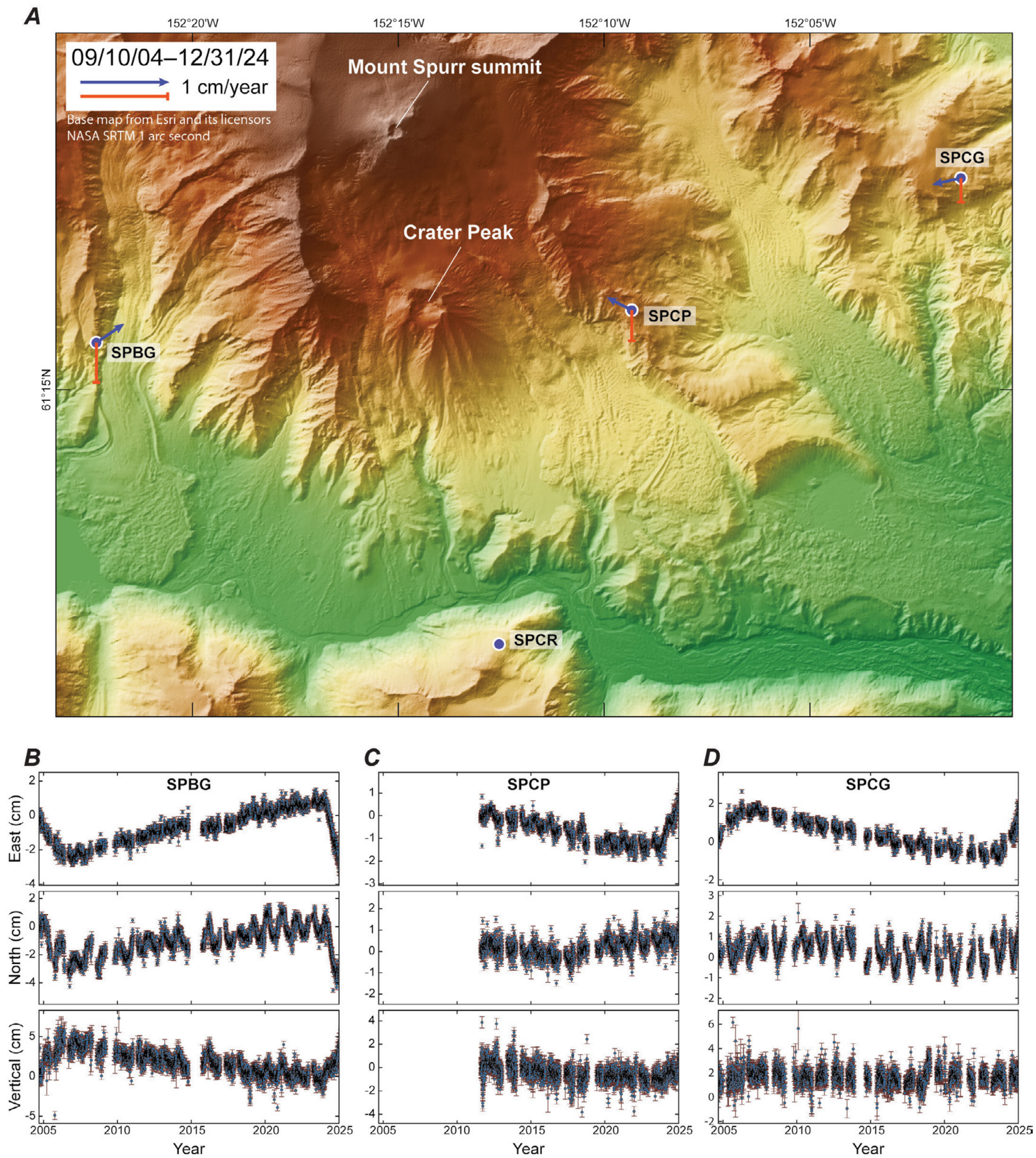

Figure 7. (A) Map of Mount Spurr showing long-term horizontal (blue) and vertical (red) GNSS network velocities and time series at stations (B) SPBG, (C) SPCP, and (D) SPCG relative to SPCR for the period September 10, 2004, through December 31, 2024.

associated with fluid movement) occurred very shallowly (<5 km; fig. 4) throughout the year. Of further note are four larger (M>2.0) earthquakes that occurred during this unrest in 2024, starting in October. These events locate north to northwest from the summit of Mount Spurr and range in magnitude from M2.0–2.9 and are of shallow depths (<4 km; fig. 5). Additional shallow earthquakes of this size occurred in early January 2025 but are not otherwise discussed here. Episodes of seismic tremor were also located east of the volcano at mid- to deep-crustal depths during 2024 (fig. 5).

Deformation observations with GNSS began at Mount Spurr during the 2004–2006 unrest. Figure 7 gives an overview of the long-term velocities recorded by the GNSS network, relative to station SPCR, which is south of Crater Peak. Assessing the individual time series shows that this long-term deformation signal is composed of three distinct episodes: 2004–2006 inflation, 2006–2024 deflation, and inflation that began in about January 2024 and continued through the end of the year.

The inflation in 2024 was recorded across the entire Mount Spurr GNSS network (fig. 8), showing uplift and motion outward and away from the summit. The onset is masked by seasonal deformation and thus difficult to determine exactly, but appears to start in late January or early February 2024. A Sentinel-1 InSAR interferogram that spans September 2023 until September 2024 is incoherent at high elevation but shows a fringe of phase change in the lower valleys around Mount Spurr and Crater Peak (fig. 9).

Preliminary modeling explains most of the inflation with an ellipsoidal pressure source with a centroid at about 6 km depth, offset to the west-northwest of Mount Spurr's summit by 1–2 km, and a volume increase of ~0.02 km^3. This is notably different from the 2004–2006 inflation determined by Lu and Dzurisin (2014), who placed it at ~14 km depth and north of the summit of Mount Spurr, the same location that our preliminary modeling of GNSS data places

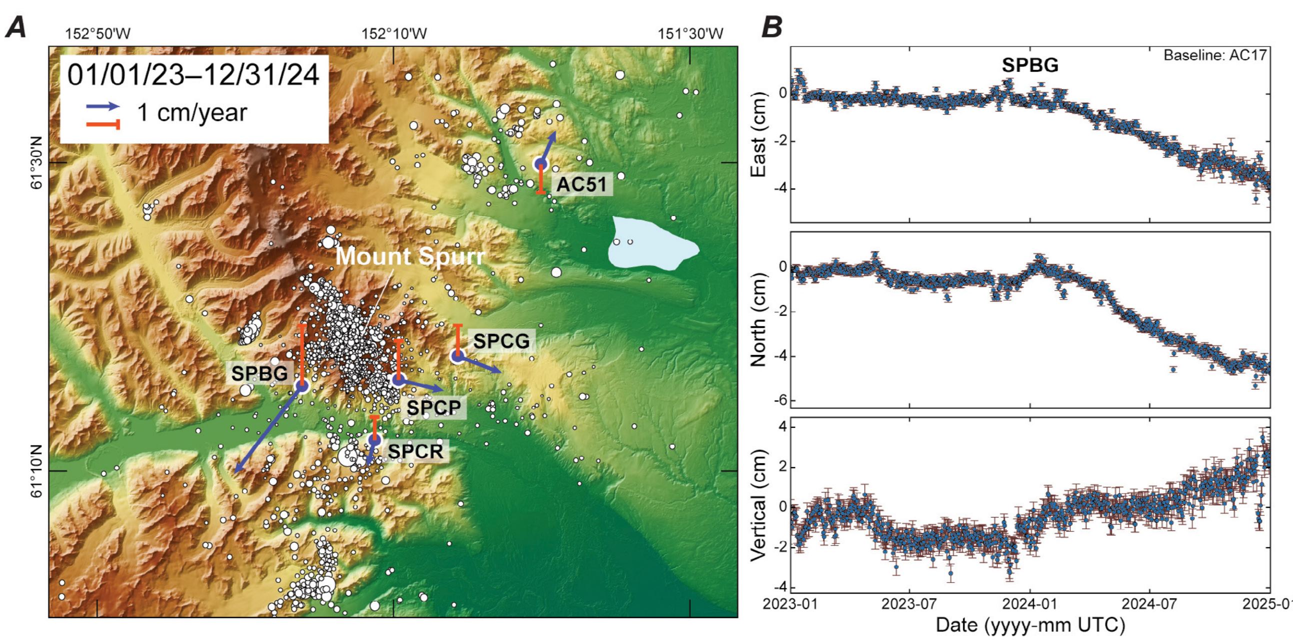

Figure 8. (A) Map of Mount Spurr and surrounding area showing horizontal (blue) and vertical (red) GNSS network velocities calculated from January 1, 2023, through December 31, 2024, relative to station AC17 near Redoubt Volcano (station not visible on map). (B) Daily position time series for SPBG in east, north, and vertical components relative to AC17 over the same time interval showing motion to the southwest and uplift. Dates are given in year-month format.

the 2006–2023 deflation source.

Gas measurement flights on June 23 and December 18, 2024 (fig. 4 and fig. 10) found emissions consistent with background degassing observed since about 2010. Emission rates were low (SO_2 < 50 t/d), and the compositions (H_2O–CO_2–SO_2–H_2S–HCl) indicated that the gases were derived from Mount Spurr's magmatic-hydrothermal system, with evidence of interactions with local rocks and/or waters prior to emission at the surface. No major differences in gas compositions were noted between the two flights, although a shift in sulfur speciation driven by a decrease in the relative proportion of H_2S was observed. Given the limited dataset, the exact reason for the change in sulfur speciation is difficult to determine, but could potentially have resulted from either: (1) gas-phase condensation reactions (e.g., $2H_2S + SO_2 \rightarrow 3S + 2H_2O$) that preferentially consumed H_2S and produced native sulfur; or (2) a modest increase in temperature of the system (~30–90°C), which would favor the production of SO_2.

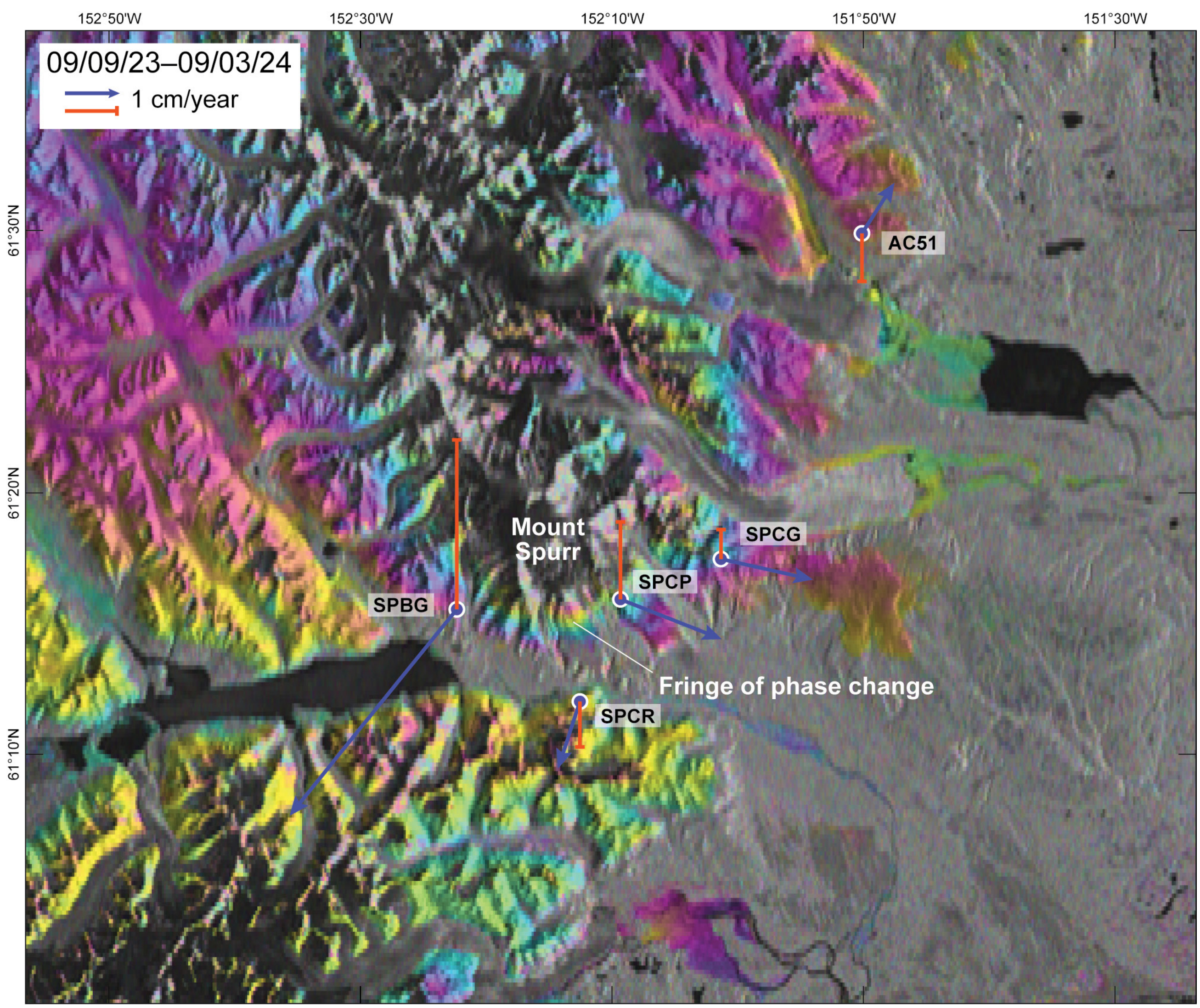

Figure 9. Sentinel-1 interferogram spanning September 9, 2023, until September 3, 2024, on path 131, frame 388, showing one fringe of phase change around Mount Spurr's summit and Crater Peak, where coherence was maintained at lower elevations.

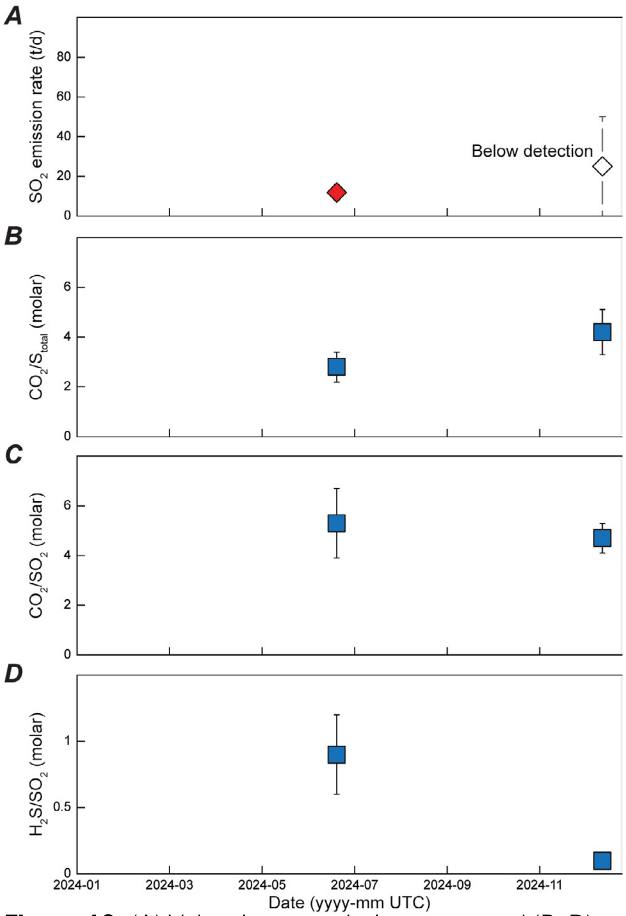

Figure 10. (A) Volcanic gas emissions rates and (B–D) composition data (with error bars) from gas flights at the summit of Mount Spurr on June 23 and December 18, 2024. $S_{total} = SO_2 + H2_S$.

Mount Katmai (Novarupta)

GVP# 312170
58.279°, −154.953°
2,057 m
Alaska Peninsula

RESUSPENSION OF 1912 ASH

Mount Katmai is located on the Alaska Peninsula about 160 km northeast of City of Kodiak, Alaska, and 430 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/katmai). The 1912 eruption of Mount Katmai and its satellite vent Novarupta was the largest eruption of the 20th century globally (Hildreth and Fierstein, 2000), producing approximately 17 cubic kilometers (km^3) of tephra-fall deposits and 11 km^3 of pyroclastic material (total dense-rock equivalent volume of ~13.5 km^3) that filled nearby valleys on both sides of the Aleutian Range (Hildreth and Fierstein, 2012). The pyroclastic deposit in these valleys is as much as 200 m thick, and some areas remain almost entirely devoid of vegetation more than a century after the eruption. When the landscape is free of snow, and particularly when the ground has little moisture content, strong winds can pick up ash and create clouds of resuspended ash. The wind can then transport the resuspended ash, often southeast across Shelikof Strait, Kodiak Island, and the Gulf of Alaska, but also in other directions. These ash clouds are often seen by individuals downwind and are recorded in satellite and webcam imagery, where they appear to originate from a broad area rather than a specific volcanic source. Resuspended ash is composed primarily of volcanic glass shards that are physically identical to ash produced in volcanic eruptions and can therefore pose hazards to aircraft operation (Hadley and others, 2004) and human health. Although these clouds resemble dispersing volcanic ash clouds in satellite imagery, they are not the result of present-day volcanic activity.

This resuspension phenomenon has been observed and documented many times during the past several decades (Hadley and others, 2004; Wallace and Schwaiger, 2019), including four times in 2024 (table 5, fig. 11). AVO issued Information Statements for each of these events, and the National Weather Service Alaska Aviation Weather Unit issued significant meteorological information statements for aviators. The four resuspension events occurred in late summer and the fall, and all were driven by winds from the northwest. Ash was lifted to an altitude of 5,000–6,000 ft (~1,500–1,800 m) ASL and was carried southeast toward Kodiak Island, although only the November 18 event was reported to have resulted in ash deposition there. No changes in the Aviation Color Code and Volcano Alert Level were warranted, and Mount Katmai remained **GREEN** and **NORMAL** throughout the year (table 4).

Table 5. Instances of significant resuspension of volcanic ash from the 1912 eruption of Mount Katmai showing dates, wind directions, and maximum cloud heights.

Date in 2024	Wind direction from	Max cloud height, ft (km)
August 26	Northwesterly	5,000 ft
September 26	Northwesterly	6,000 ft
October 18–20	Northwesterly	6,000 ft
November 18	Northwesterly	6,000 ft

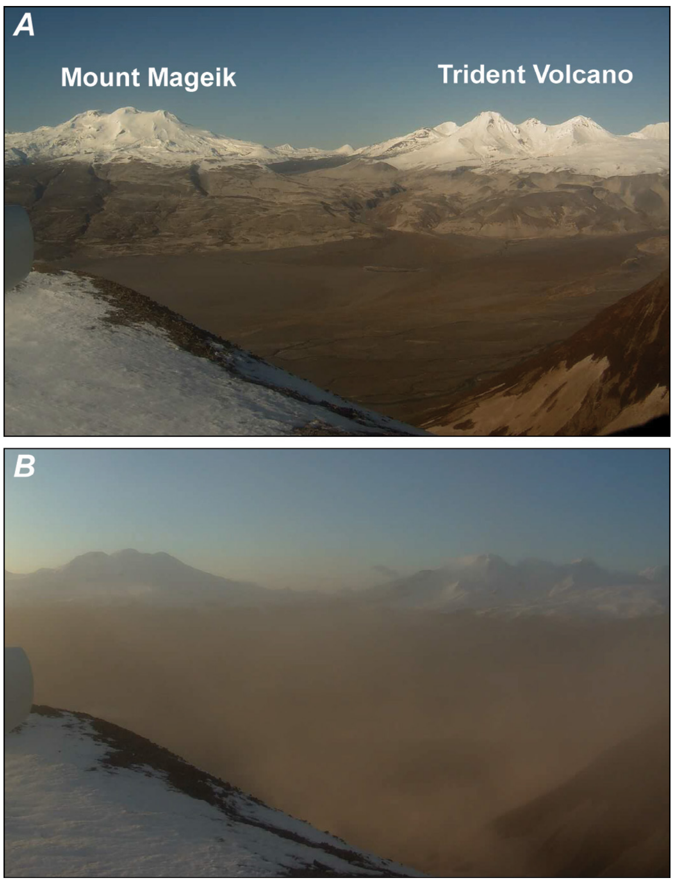

Figure 11. Webcam images from station KAB2, looking northwest across the Katmai River valley toward Trident Volcano and Mount Mageik, located south of Mount Katmai, comparing (A) clear viewing conditions on October 16 to (B) dusty conditions October 18, during an ash resuspension event.

Trident Volcano

GVP# 312160
58.234°, −155.103°
1,849 m
Alaska Peninsula

WANING SEISMICITY FOLLOWING 2022-2023 INTRUSIVE ACTIVITY

Trident Volcano, a part of the Mount Katmai group of volcanoes within Katmai National Park and Preserve on the Alaska Peninsula, is located 148 km southeast of King Salmon, Alaska, and 440 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/trident). Trident Volcano consists of a complex of four cones and several lava domes, all andesite to dacite in composition, as high as 1,849 m. An eruption beginning in 1953 produced about 0.5 km^3 of fragmental material (an initial ash plume rose to ~30,000 ft [~9,100 m] ASL) and intercalated lava flows that constructed a new cone, known informally as Southwest Trident (Coombs and others, 2000; Hildreth and others, 2000). The eruption continued sporadically until 1974. Fumaroles remain active on the summit of Southwest Trident and on the southeast flank of the oldest, central cone.

An upward-migrating earthquake swarm began beneath Trident Volcano in August 2022, marking the start of a prolonged period of unrest interpreted as a magmatic intrusion (fig. 12; Orr and others, 2025; Nastan and others, in press). The Aviation Color Code and Volcano Alert Level were elevated to **YELLOW** and **ADVISORY** from late September to mid-October 2022 in response. The rate of shallow earthquakes nearby at Mount Martin and Mount Mageik increased at around the same time, probably related to stress changes in the crust or changes in the shallow hydrothermal system in response to the movement of magma beneath Trident Volcano. Seismicity waxed and waned over the following months, and the volcano was again elevated to **YELLOW** and **ADVISORY** in late February 2023.

A notable increase in low-frequency earthquakes in the area between Trident Volcano and Novarupta started in May 2023 (fig. 12), and satellite radar data collected in June 2023 showed slight uplift of the volcano since May 2022 (Nastan and others, in press). The elevated

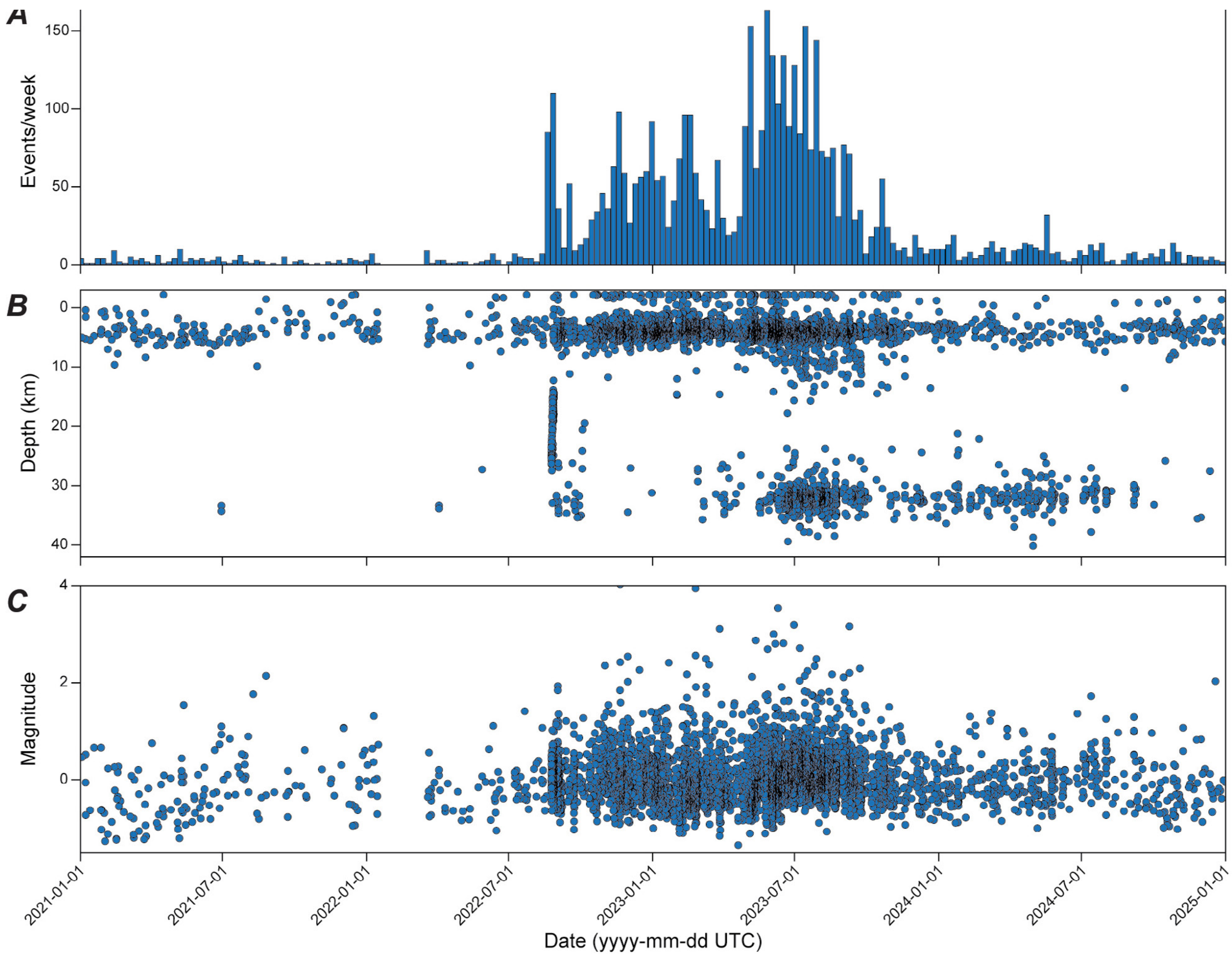

Figure 12. Plots showing (A) weekly rate, (B) depths, and (C) magnitudes of earthquakes located by the Alaska Volcano Observatory within 5 km of Trident Volcano from the beginning of 2021 through to the end of 2024. Heightened activity began in late 2022. A second notable increase occurred in May 2023, and activity waned in late 2023 to return to background rates in January 2024. Dates are given in year-month-day format.

seismicity continued throughout 2023 but began to decline as the year ended. By early January 2024, seismicity in the area had fallen to background level (fig. 12), and the Aviation Color Code and Volcano Alert Level were lowered to **GREEN** and **NORMAL** on January 10 (table 4), marking the end of the seismic crisis. No other significant seismicity was recorded throughout the rest of the year.

Shishaldin Volcano

GVP# 311360
54.755°, −163.971°
2,858 m
Unimak Island, Fox Islands, Aleutian Islands

WANING SEISMICITY FOLLOWING 2023 EXPLOSIVE ERUPTION

Shishaldin Volcano is a spectacular symmetrical cone with a basal diameter of ~16 km. It lies near the center of Unimak Island in the eastern Aleutian Islands, 95 km southwest of the City of Cold Bay and 1,095 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/shishaldin). Shishaldin Volcano is one of the most active volcanoes in the Aleutian Arc

(Miller and others, 1998); most of its historical eruptions produced small ash and steam plumes, although an April-May 1999 eruption produced Strombolian explosions, lahars, and a subplinian ash cloud that reached 52,000 ft (~16,000 m) ASL (Nye and others, 2002; Stelling and others, 2002).

Shishaldin Volcano became restless again in late 2017, with the generation of seismic and infrasound signals consistent with weak explosive activity that lasted into early 2018 (Dixon and others, 2020), although no ash emissions were observed. Then, from July 2019 to March 2020, the volcano erupted more spectacularly, producing Strombolian explosions, feeding lava flows and lahars down the flanks of the cone, and sending ash as high as 30,000 ft (~9,100 m) ASL (Orr and others, 2023; Orr and others, 2024a; Loewen and others, unpub. data). After three years of relative quiescence, the volcano began to erupt again in summer 2023, producing 13 paroxysms from July to November (Nastan and others, in press; Loewen and others, unpub. data). The final explosive eruption in 2023 occurred on November 2–3, followed by moderately high levels of volcanic tremor and recurring long-period events over the next couple of months (Fee and others, 2026).

Although no explosive activity occurred at the volcano in 2024, unrest continued throughout the year (fig. 13). On January 2, 2024, AVO lowered the Aviation Color Code and Volcano Alert Level to **YELLOW** and **ADVISORY** (table 4) due to decreasing gas emissions and geophysical

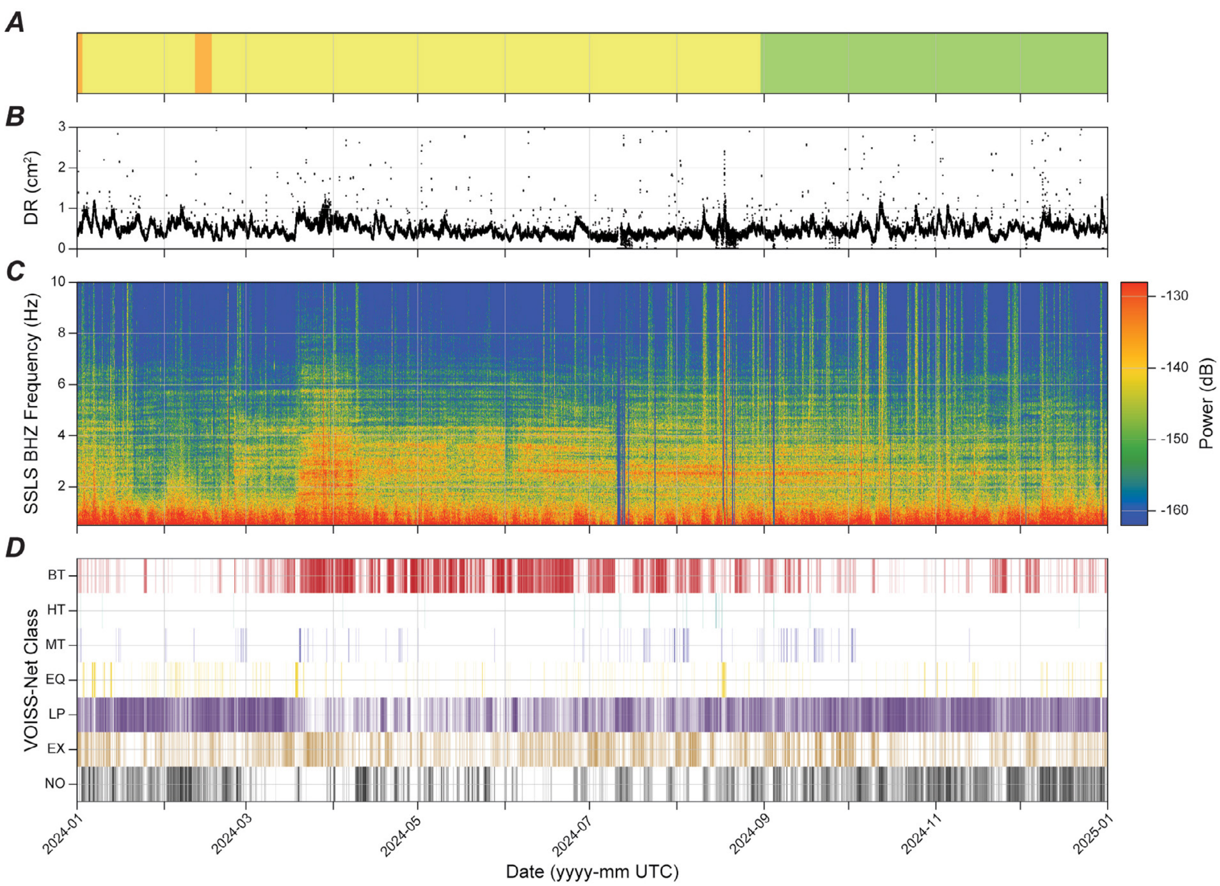

Figure 13. Timeline of unrest at Shishaldin Volcano during 2024, showing (A) Aviation Color Code and Volcano Alert Level (green is GREEN/NORMAL, yellow is YELLOW/ADVISORY, orange is ORANGE/WATCH), (B) reduced displacement (DR), which is a common amplitude metric, (C) the spectrogram for station SSLS, and (D) the VOISS-Net seismic classification, determined using the machine learning algorithm of Fee and others (2025) and Tan and others (2024). BT is Broadband Tremor, HT is Harmonic Tremor, MT is Monochromatic Tremor, EQ is Earthquake, LP is Long-Period Earthquake, EX is Explosion, NO is Noise. Dates are given in year-month format

signals. Seismicity afterward in January consisted primarily of repeating long-period earthquakes that continued to decline in amplitude.

On February 11, AVO lowered the Aviation Color Code and Volcano Alert Level back to **ORANGE** and **WATCH** in response to weak ash emissions observed in clear webcam images (table 4; fig. 14). Retrospective analysis of geophysical and remote sensing data indicated that the ash likely resulted from small collapses from the walls of the northeast–southwest-trending graben-like notch. This feature formed when the northeast and southwest walls of the summit crater subsided and episodically collapsed near the end of the 2023 eruption sequence (fig. 15). The small wall collapses in 2024 were not related to elevated volcanic activity and presented a hazard only near the upper flanks of the volcano. With the absence of eruptive activity, the Aviation Color Code and Volcano Alert Level were further lowered to **YELLOW and ADVISORY** on February 17 (table 4). Additional collapses from the walls of the notch were observed in remote sensing data over the next several months, and minor amounts of ash on the upper flanks were occasionally visible in webcam images.

In mid-March, AVO observed an increase in seismicity consisting of semi-continuous tremor rather than discrete long-period events (fig. 13). This lasted for about three weeks and then decreased over the next few months. The seismicity thereafter was characterized by repeating long-period events, which AVO soon considered representative of a new background level. The volcano was watched closely during this period, but the unrest was deemed not significant

Figure 14. Zoomed and cropped image of Shishaldin Volcano from AVO webcam BRPK captured at 18:25 on February 11, 2024, showing weak ash emissions at the summit of the volcano.

enough to warrant a change to the Aviation Color Code and Volcano Alert Level.

Field crews visited Shishaldin Volcano in summer 2024 and obtained excellent views of the summit notch and two pits on the floor of the bisected crater—one active and the other not (fig. 15). The active pit was the source of continuous gas emissions, although no elevated temperatures were detected, which is consistent with the limited number of thermal anomalies detected in remote sensing data.

Weak infrasound signals were also observed in 2024. The infrasound signals first appeared in mid-March, with their occurrence potentially related to the increase in seismic tremor observed at that time. For the rest of the year, the infrasound signals accompanied the long-period events and were visible on the local seismoacoustic network when noise levels were low. Figure 16 shows some typical infrasound waveforms recorded on stations SSLN and SSLS from March and October 2024. The infrasound signals were low amplitude (<0.2 Pa peak), had an impulsive onset, and coda of approximately 5–10 s.

Gas emissions were regularly observed when viewing conditions permitted, and sulfur dioxide (SO_2) was also intermittently detected via the satellite-based TROPOMI sensor throughout the year. This suggests that shallow, residual magma from the 2023 explosive eruption sequence was still degassing (Lopez and others, unpub. data).

Based on visual observations in summer 2024, and compared with other infrasound signals at similar volcanoes, the unrest at Shishaldin

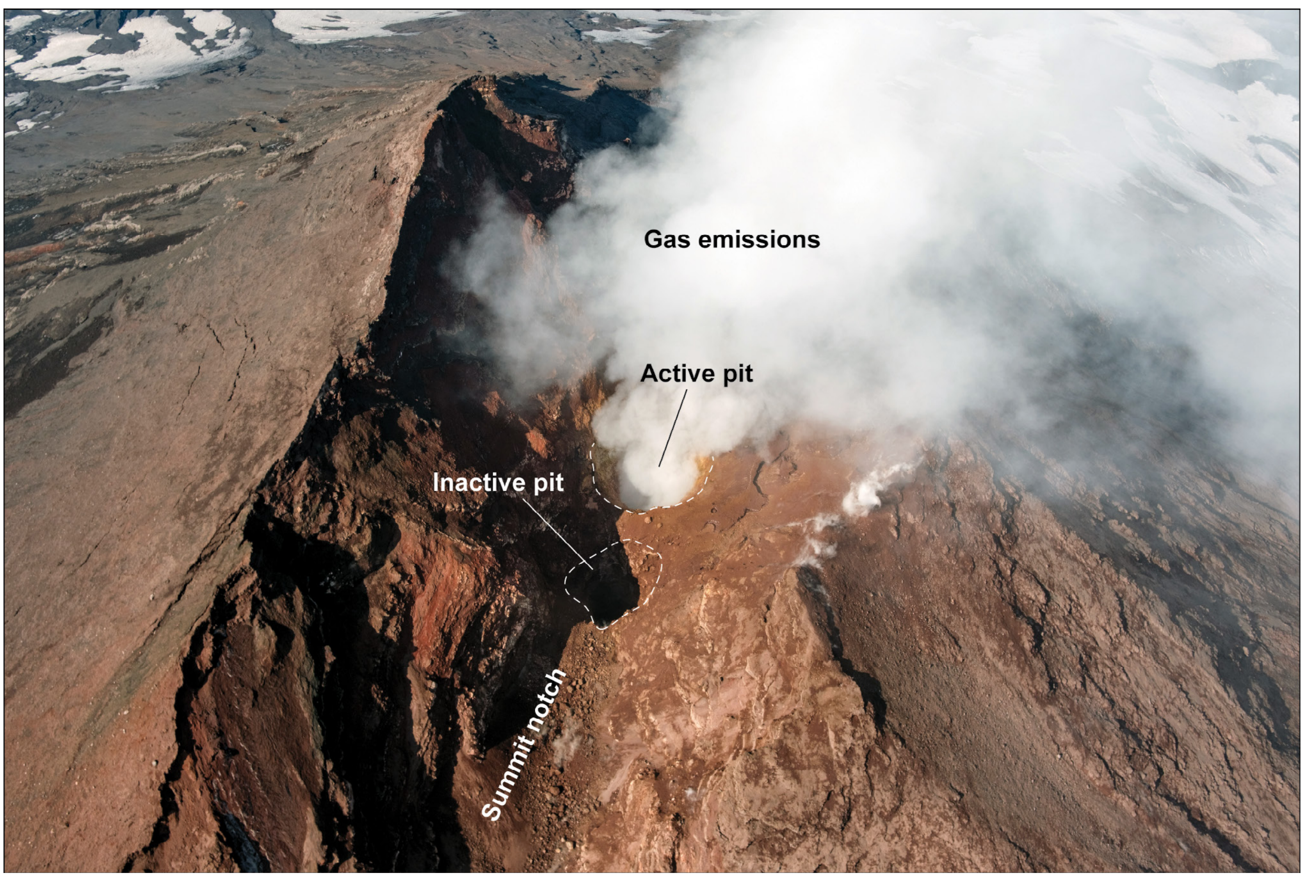

Figure 15. Oblique aerial photograph of Shishaldin Volcano's summit, looking southwest, on August 1, 2024, showing two pits—one active and the other inactive. Gas emissions and infrasound signals originated from the active pit throughout 2024. The summit of the volcano was significantly modified during the 2023 explosive eruption sequence, forming a graben-like notch that extended northeast–southwest across the summit. Photograph by M. Loewen, U.S. Geological Survey.

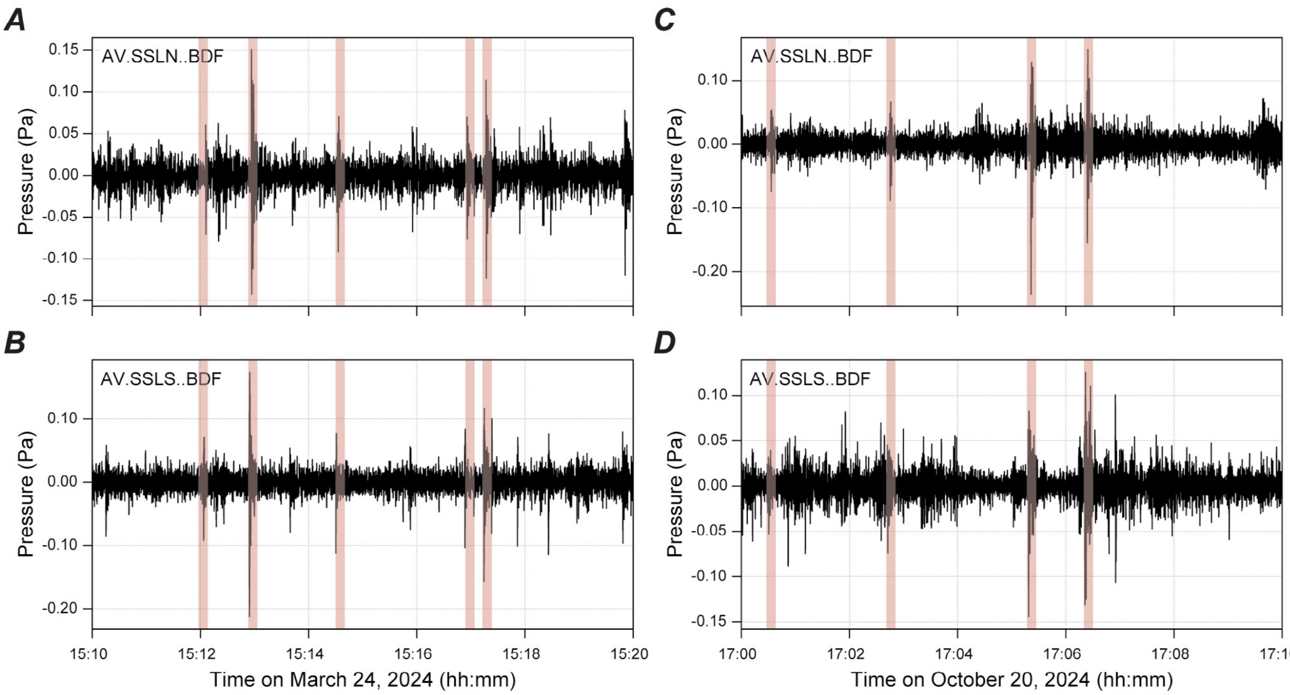

Figure 16. Graphs showing typical low-amplitude infrasound signals from stations SSLN and SSLS at Shishaldin Volcano in (A–B) March 2024, and (C–D) October 2024, with prominent examples indicated by the red bars. The signals were only apparent when noise levels were low. Times are given in hour:minute format.

Volcano likely represented discrete, energetic gas release deep within the summit crater. The infrasound signals and long-period earthquakes in 2024 resemble similar signals documented at the volcano in prior years, especially in the years following the 1999 eruption (Caplan-Auerbach and Petersen, 2005; Petersen and others, 2006).

Although gas emissions, seismicity, and infrasound signals from Shishaldin Volcano continued at low levels, AVO decided that these signals represented the new background level of activity following the 2023 eruption. Thus, on August 30, AVO lowered the Aviation Color Code and Volcano Alert Level to GREEN and NORMAL (table 4). The gas and geophysical signals continued for the remainder of the year.

Mount Cleveland

GVP# 311240
52.822°, −169.945°
1,745 m
Chuginadak Island,
Islands of Four Mountains, Aleutian Islands

ELEVATED SURFACE TEMPERATURES, GAS EMISSIONS

Mount Cleveland forms the west side of the uninhabited Chuginadak Island, which is part of the Islands of the Four Mountains group in the east-central Aleutian Islands (fig. 1; https://avo.alaska.edu/volcano/cleveland). Mount Cleveland is ~75 km west of the community of Nikolski and 1,525 km southwest of Anchorage. Its historical eruptions have been characterized by short-lived ash explosions, lava fountaining, lava flows, and pyroclastic flows. In February 2001, after 6 years of quiescence, Mount Cleveland had three explosive events that sent ash to altitudes as high as ~30,000 ft (~9,100 m) ASL, produced a pyroclastic flow that reached the ocean, and erupted a blocky lava flow (Dean and others, 2004; McGimsey and others, 2005). Intermittent explosive eruptions took place every year thereafter from 2001 to 2020 (Iezzi and others, 2020)—the last explosive eruption at Mount Cleveland occurred in June 2020 (Orr and others, 2024a). No eruptive activity has been documented at Mount Cleveland since then, although gas emissions from the volcano's summit are often seen in webcam data when the weather is clear, and a thermal anomaly is occasionally observed in satellite data (for example, Orr and others, 2024b).

On July 5, 2024, a combination of a robust gas plume, a strong summit thermal anomaly, elevated SO_2 emissions, and weak signals detected on the local infrasound network prompted AVO to raise the Aviation Color Code and the Volcano Alert Level to **YELLOW** and **ADVISORY** (table 4). Over the following few days, AVO determined that the observed SO_2 emissions, thermal anomaly, and outgassing plume were much like those detected previously at Mount Cleveland, and the weak infrasound signals may have been related to surf noise. The elevated unrest was deemed a false alarm, and the Aviation Color Code and the Volcano Alert Level were lowered back to **GREEN** and **NORMAL** on July 8 (table 4).

Atka volcano (Korovin Volcano)

GVP# 311160
52.379°, −174.155°
1,546 m
Atka Island, Andreanof Islands, Aleutian Islands

SMALL EXPLOSION

Atka volcano, which forms the northern part of Atka Island, lies ~15 km north of the City of Atka and ~1,760 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/atka-volcanic-complex). Atka volcano consists of several cones, including Mount Kliuchef and Korovin Volcano, which have been active in the Holocene, and several older peaks that are the remnants of Pleistocene volcanoes. Mount Kliuchef is composed of a series of five vents aligned northeast–southwest. Its two main summit vents appear young—the eastmost was probably the source of an eruption in 1812 attributed to nearby Sarichef Volcano (Wood and Kienle, 1990). Korovin Volcano, ~6 km north of Mount Kliuchef, is a compound stratovolcano with two summit craters spaced 600 m apart (Miller and others, 1998). The southeast crater, which is the most recently active of the two, is ~1 km wide at the rim and holds a small, somewhat ephemeral lake. The lake sits about 175 m below the immediately adjacent east rim of the crater.

A short-lived impulsive event at Korovin Volcano, interpreted as an explosion, was captured on local seismic and infrasound stations in the evening of March 27, 2024 (fig. 17). The event, which occurred at 03:36 on March 28, may have been related to phreatic activity within Korovin Volcano's crater lake. In response, the Aviation Color Code and the Volcano Alert Level were elevated to **YELLOW** and **ADVISORY** shortly afterward (table 4). Three episodes of tremor, each lasting several minutes, were recorded on nearby seismic stations during the following few hours after the explosion. No ash emissions were detected in satellite imagery though, and webcam imagery of the summit of the volcano after the event showed clean snow with no evidence of ash deposition, indicating the explosion was small, with any material ejected presumably being confined to the crater. With no further activity, the volcano was lowered back to **GREEN** and **NORMAL** on April 9 (table 4).

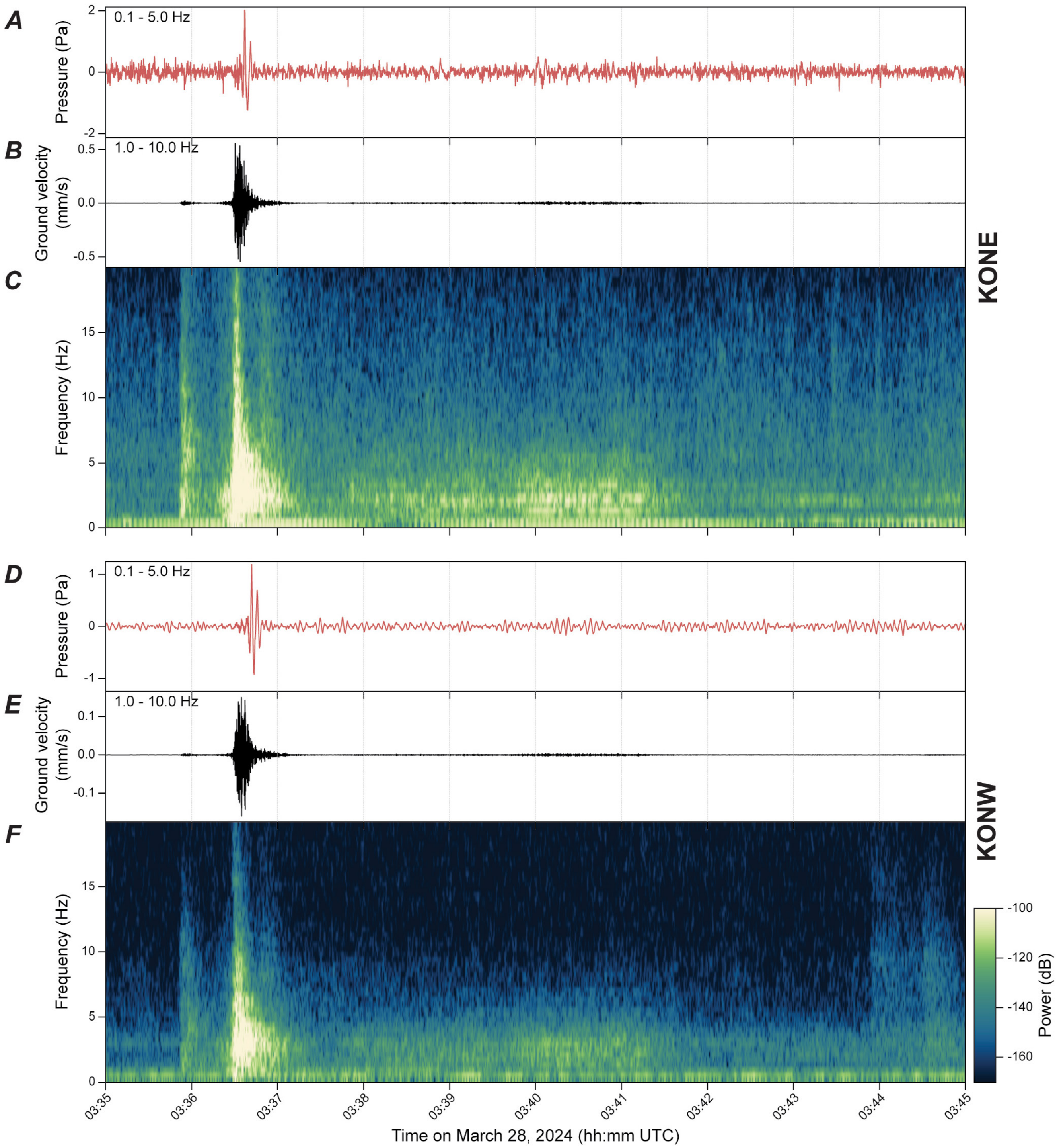

Figure 17. Plots showing seismic and infrasound recordings of a small explosion at Korovin Volcano at stations KONE (A–C) and KONW (D–F) on March 28, 2024. Infrasound data are plotted in red (A, D), and seismic traces are plotted in black (B, E). Spectrograms (C, F) are for seismic data. Times are given in hour:minute format.

Great Sitkin Volcano

GVP# 311120
52.077°, −176.111°
1,743 m
Great Sitkin Island,
Andreanof Islands, Aleutian Islands

ERUPTION OF LAVA FLOW

Great Sitkin Volcano is a basaltic andesite volcano located 40 km northeast of the City of Adak, Alaska, and 1,880 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/great-sitkin). It constitutes most of the northern half of Great Sitkin Island, part of the Andreanof Islands group of the central Aleutian Islands (Waythomas and others, 2003a, 2003b). The volcano consists of an older caldera that is partly filled by a younger parasitic cone, which itself contains a summit crater 2–3 km in diameter partly filled by young lava flows.

Great Sitkin Volcano erupted at least twice in the 20th century. In 1974, a lava dome formed in the summit crater during which time at least one ash cloud, with a maximum altitude of ~10,000 ft (~3,000 m) ASL, was observed (Associated Press, 1974). A poorly documented eruption in 1945 also produced a lava dome, which was then partially destroyed by the 1974 eruption. A relatively recent eruption, thought to have occurred within the past 280 years, appears to have produced pyroclastic flows that partly filled a valley on the southwest flank of the volcano (Waythomas and others, 2003b).

In late July 2016, Great Sitkin Volcano entered a period of increased unrest characterized by elevated seismicity, anomalous steaming from its summit crater, and small phreatic explosive events (Dixon and others, 2020). Activity fell to background levels in 2020, but picked up again in early 2021 with increasing seismicity, warming surface temperatures, and gas emissions. This escalation culminated with a vulcanian explosion on May 25, 2021. After a hiatus in eruptive activity, a dome-building effusive eruption began in mid-July of that year, gradually filling the summit crater, overtopping the crater rim in two places, and displacing the intracrater glacier (Orr and others, 2024b). Lava effusion has continued unabated thereafter, and AVO has assigned an Aviation Color Code and Volcano Alert Level of **ORANGE** and **WATCH** since 2021 (table 4; Orr and others, 2024b; Orr and others, 2025; Nastan and others, in press). The effusive eruption is characterized by lava flowing away from the vent, stalling, inflating, and then breaking out from the vent again as a new flow. We define the onset of each distinct period of flow effusion after stalling as the start of a new phase, with phase 1 lasting from July 2021–July 2022 and phase 2 lasting from July 2022–December 2023 (fig. 18).

Lava flow activity in 2024 started with a new northward flow lobe that began erupting from a large crack in the crust of the inflated phase 2 lava flow above the vent by January 2, marking the start of phase 3 (fig. 18 and fig. 19A). This lobe propagated to the north-northwest, reaching a final length of 280 m by late July (fig. 19B), and was accompanied by continued inflation above the vent. The north-northwest flow lobe was superseded by flow lobes that began advancing to the east-northeast and southwest in June (fig. 19C). These were not considered new phases because they all erupted concurrently and were not separated by pauses in effusion.

The eruption of the southwest lobe of phase 3 was short-lived, lasting just 2 months and reaching a length of 200 m. The east-northeast flow lobe, on the other hand, dominated expansion of the flow field, advancing across the phase 2 flow and onto the phase 1 flow, reaching a length of 400 m by the end of 2024 (fig. 19C). Inflation of the east-northeast lobe in December also resulted in extrusion of a small north-propagating flow lobe from its northern margin (fig. 19D). The north flow lobe was a few tens of meters long by the end of 2024. Advance of both the east-northeast flow lobe and the north flow lobe continued into 2025. Blocks spalling from steep flow margins generated local debris fields around the active flow fronts.

A timeline of the 2024 lava flow activity, as well as associated steaming, elevated surface temperatures, rockfalls, and seismicity is shown in figure 20. The Aviation Color Code is shown in figure 20A. The durations of the phase 3 lava lobes are depicted in figure 20B, and eruptive volumes are shown in figure 20C. The total lava effusion for 2024 was about 6×10^{6} m^3 based on the change in aerial flow extent and using a digital elevation model from September 29, 2024, to measure

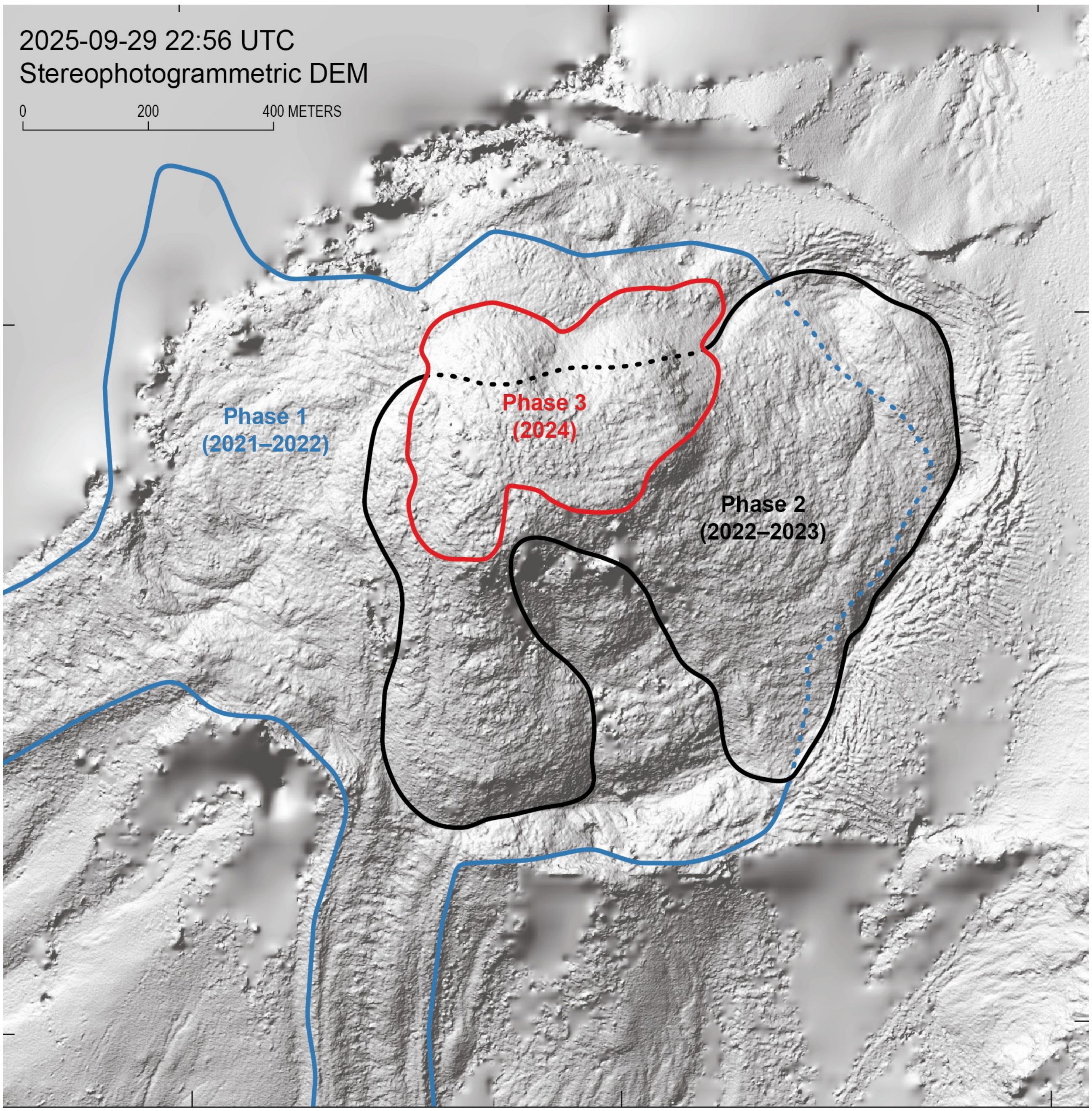

Figure 18. Hillshade terrain image of the summit of Great Sitkin Volcano, derived from satellite stereophotogrammetry from WorldView-2 imagery Maxar 2026 © USG+) acquired on September 29, 2024. The flow extents of phase 1 (2021–2022), phase 2 (2022–2023), and phase 3 (2024) lavas are outlined in blue, black, and red, respectively. The volume of phase 3 lava erupted in 2024 is about 6 million m3.

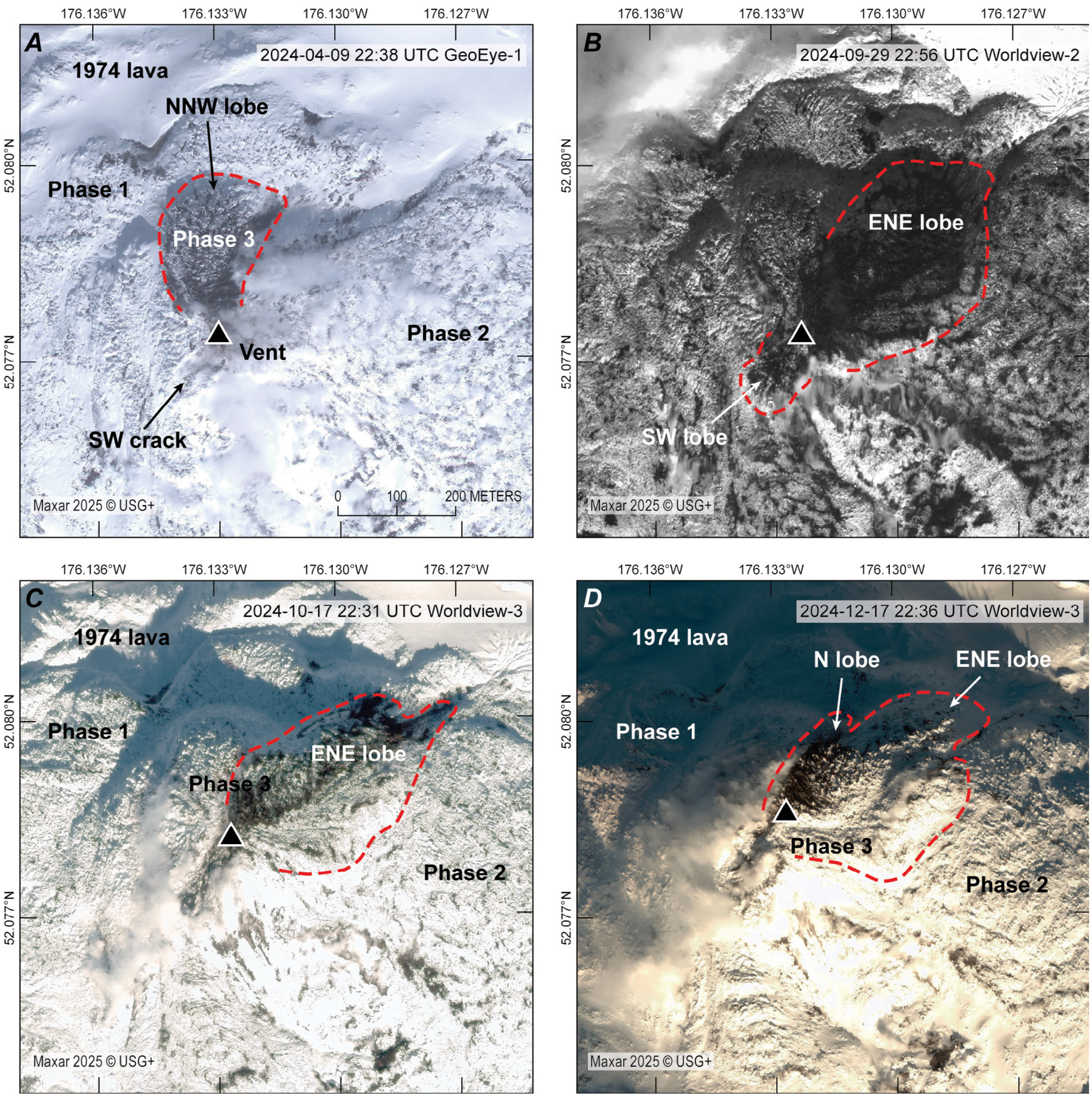

Figure 19. High-resolution satellite imagery of the Great Sitkin Volcano lava dome eruption in 2024. The vent center is marked with a triangle, and the 1974 lava flow, as well as the phase 1 (2021–2022) and phase 2 (2022–2024) flows, are labelled. The red dashed lines outline the phase 3 flow lobes active in each image. (A) April 9, 2024, image showing the active north-northwest (NNW) lobe, as well as the southwest (SW) crack radiating from the vent center of the inflating flow that would source the breakout of the short southwest (SW) lobe. (B) September 29, 2024, image showing the southwest (SW) lobe (warm, but no longer active in this image) and the active east-northeast (ENE) lobe. (C) October 17, 2024, image showing continued advance of the east-northeast (ENE) to the east over phase 2 lava and north over phase 1 lava. (D) December 17, 2024, image showing further thickening of the ENE lobe and the initiation of a new north (N) lobe. Scale is the same in all images.

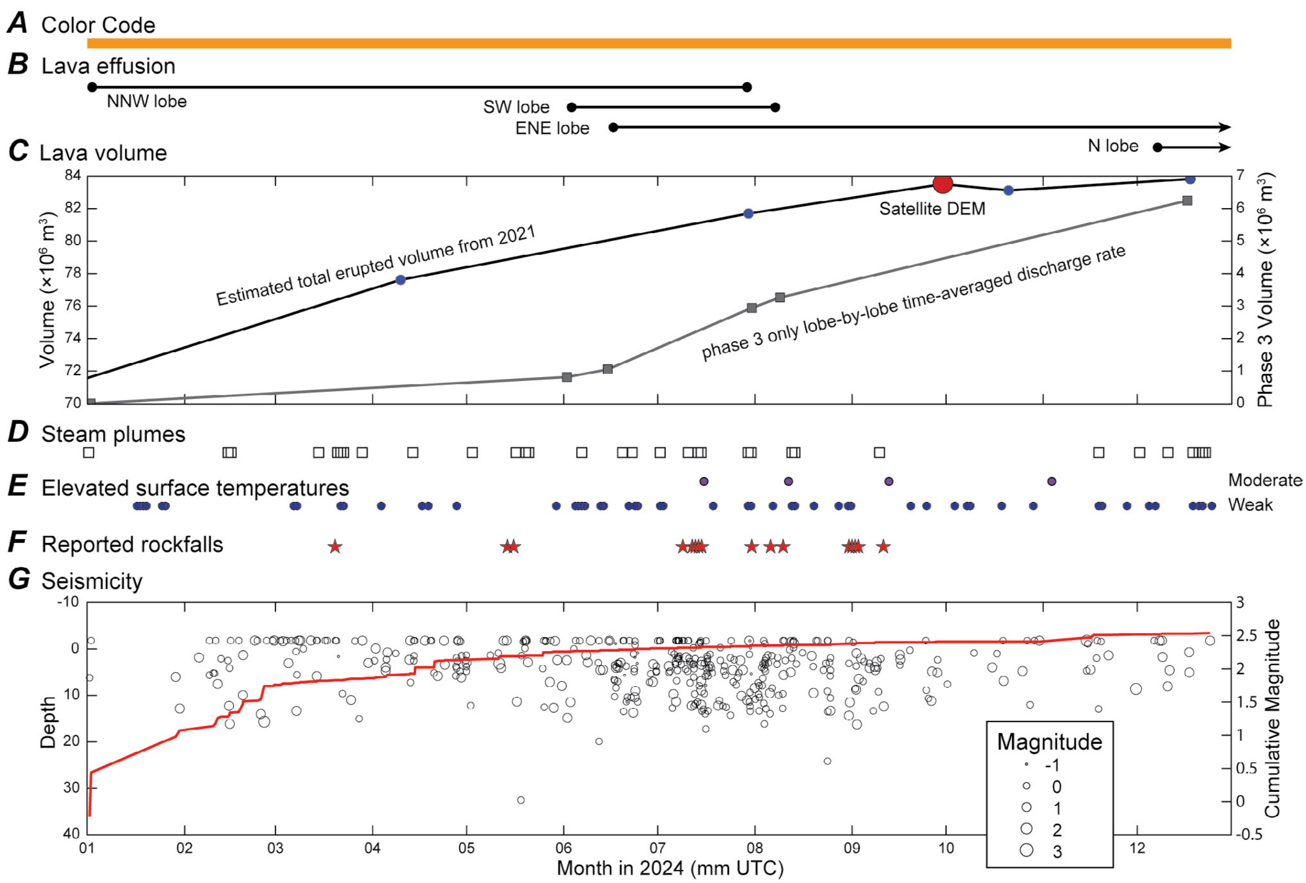

Figure 20. Chronology of the Great Sitkin Volcano eruption in 2024. (A) Color bar timeline showing the Aviation Color Code and Volcano Alert Level (orange is ORANGE/WATCH). (B) Periods of activity for each phase 3 lobe as shown in Figure 18. (C) Estimated erupted lava volume from flow extents and thicknesses, as well as rare satellite digital elevation models (DEM) (red circle; Figure 18), from the start of the eruption in 2021 (left axis) and since the start of phase 3 on 2 January 2024 (right axis). (D) Reported observations of steam plumes. (E) Reported qualitative observations of weak or moderately elevated surface temperatures. (F) Reported rockfall signals in seismic data. (G) Located earthquake timing, depth, and magnitude during 2024. Cumulative magnitude is shown with the red line (right axis). Dates are given in numerical month format.

flow thickness (fig. 18). AVO was unable to conduct field work at Great Sitkin in 2024, so all observations presented here were obtained using remote techniques.

Steaming and elevated surface temperatures from the warm and degassing lava surface (fig. 20D–E) were observed throughout the year when the weather was clear. Rockfalls were detected in seismic data on numerous occasions (fig. 20F), particularly in the summer as activity shifted to the southwest and east-northeast lobes, and when the east-northeast lobe advanced over the steep margin of the phase 2 flow and produced a rockfall debris fan. Seismicity was also highest during this period of multiple-lobe lava effusion, as evident on the timeline of seismicity (fig. 20G). 427 earthquakes were located at Great Sitkin Volcano in 2024, primarily concentrated at shallow depths and mostly associated with the eruption.

Kanaga Volcano

GVP# 311110
51.924°, −177.162°
1,296 m
Kanaga Island,
Andreanof Islands, Aleutian Islands

WANING SEISMICITY FOLLOWING PHREATIC ERUPTION IN 2023

Kanaga Volcano is a symmetrical stratovolcano located on the northern end of Kanaga Island in the western Aleutian Islands, 33 km west of the community of Adak and 1942 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/kanaga). Numerous eruptions have been recorded since the mid-1700s—the most recent event prior to 2023 was a small explosive event in 2012 that produced a small ash cloud and resulted in a NW–SE-oriented summit fracture (Herrick and others, 2014). Active fumaroles persist in the summit region and hot springs occur near the base of the volcano. AVO monitors the volcano with local seismic stations, a single infrasound sensor, and a webcam, as well as regional infrasound and lightning networks and a variety of satellite data.

A M_L2.6 earthquake followed closely by a small explosion, likely phreatic, occurred at Kanaga Volcano at 07:31 on December 19 2023 (Nastan and others, in press). The Aviation Color Code and Volcano Alert Level were raised to **YELLOW** and **ADVISORY** in response. Subsequent high-resolution satellite imagery showed new gaping cracks, steaming profusely, extending across the summit of the volcano, subparallel to those that opened in 2012. Although no further eruptive activity or cracking occurred, seismicity remained elevated for several weeks, finally dropping to background levels in late February 2024 (fig. 21). The Aviation Color Code and Volcano Alert Level were lowered to **GREEN** and **NORMAL** on February 27 (table 4). Gas emissions from near the intersection of the 2012 and 2023 crack systems persisted through the end of the year (fig. 22).

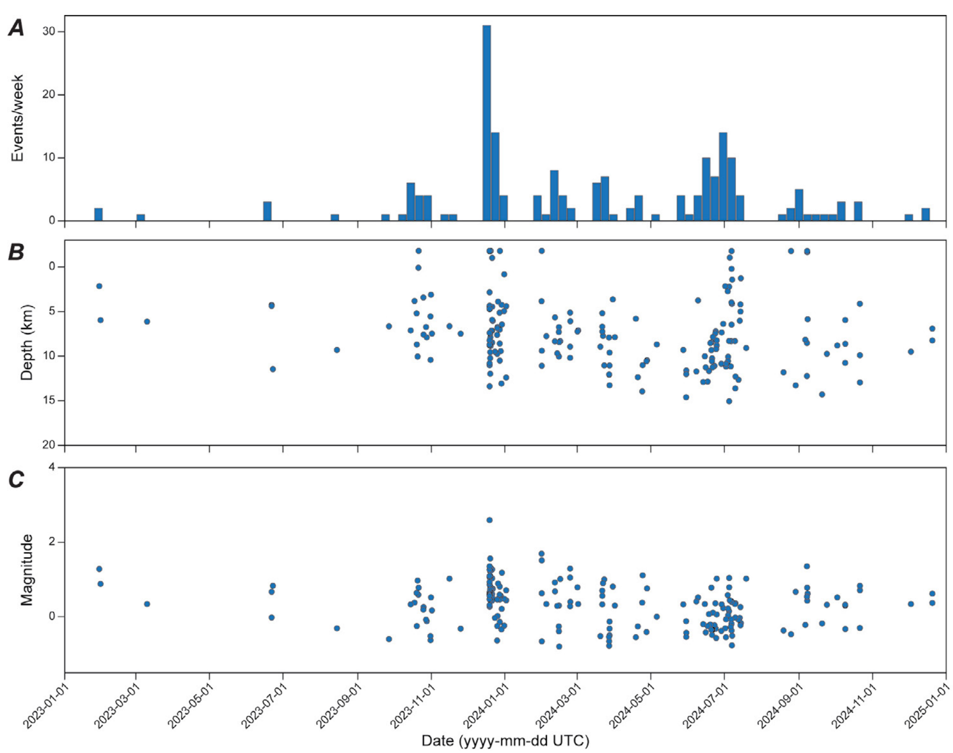

Figure 21. Plots showing weekly rate (A), depths (B), and magnitudes (C) of earthquakes located by the Alaska Volcano Observatory within 5 km of Kanaga Volcano from the beginning of 2023 through to the end of 2024. Heightened activity began in late 2023 and returned to background rates in January 2024. A second increase in earthquake seismicity occurred from mid-June through early July. Dates are given in year-month-day format.

Figure 22. Worldview-3 satellite image showing the summit of Kanaga at 23:04 on January 16, 2024. Dashed orange lines indicate cracks formed in 2023; dotted orange lines indicate cracks formed in 2012; dotted black line is crater rim. The intersection of the 2012 and 2023 crack systems was the site of persistent gas emissions.

Mount Gareloi

GVP# 311070
51.789°, −178.794°
1,550 m
Gareloi Island,
Andreanof Islands, Aleutian Islands

EARTHQUAKE SWARM

Mount Gareloi, which makes up Gareloi Island, is a prominent stratovolcano located in the western Aleutian Islands, ~150 km west of Adak and ~2,000 km southwest of Anchorage (fig. 1; https://avo.alaska.edu/volcano/gareloi). Mount Gareloi has had 16 reports of eruptive activity since 1760, making it one of the most active volcanoes in the Aleutian Islands since the 1740s. The uninhabited volcano has two summit peaks (Miller and others, 1998), spaced ~500 m apart and separated by a narrow saddle, and both have been active historically (Coombs and others, 2012). The slightly higher north peak has an ~300-m-wide crater containing a small lake. The south peak has a crater that is open to the south and that hosts several active fumaroles on its west rim, often forming a conspicuous plume. Thirteen younger craters, with diameters of 80–1,600 m, are aligned on a fissure that extends south-southeastward from the southern summit to the coast (Coats, 1959). These craters formed during an eruption in 1929 that produced four blocky lava flows and blanketed the volcano's southeast flank with glassy andesitic tuff (Coats, 1959). Mount Gareloi commonly shows low-energy, long-period seismic activity sourced beneath its edifice, suggesting the presence of shallow magma interacting with a hydrothermal system (Harris and others, 2021).

A seismic swarm at Mount Gareloi was detected by the local seismic network on February 12, 2024 (fig. 23). The seismicity peaked about three hours later, and AVO raised the Aviation Color Code and Volcano Alert Level to **YELLOW** and **ADVISORY** later that day, at 22:10 (table 4). After dropping slightly, the seismicity gradually rose again over the following several hours and peaked at its highest level at around 12:00 on February 13. No corresponding signs of eruptive activity or other volcanic unrest were observed

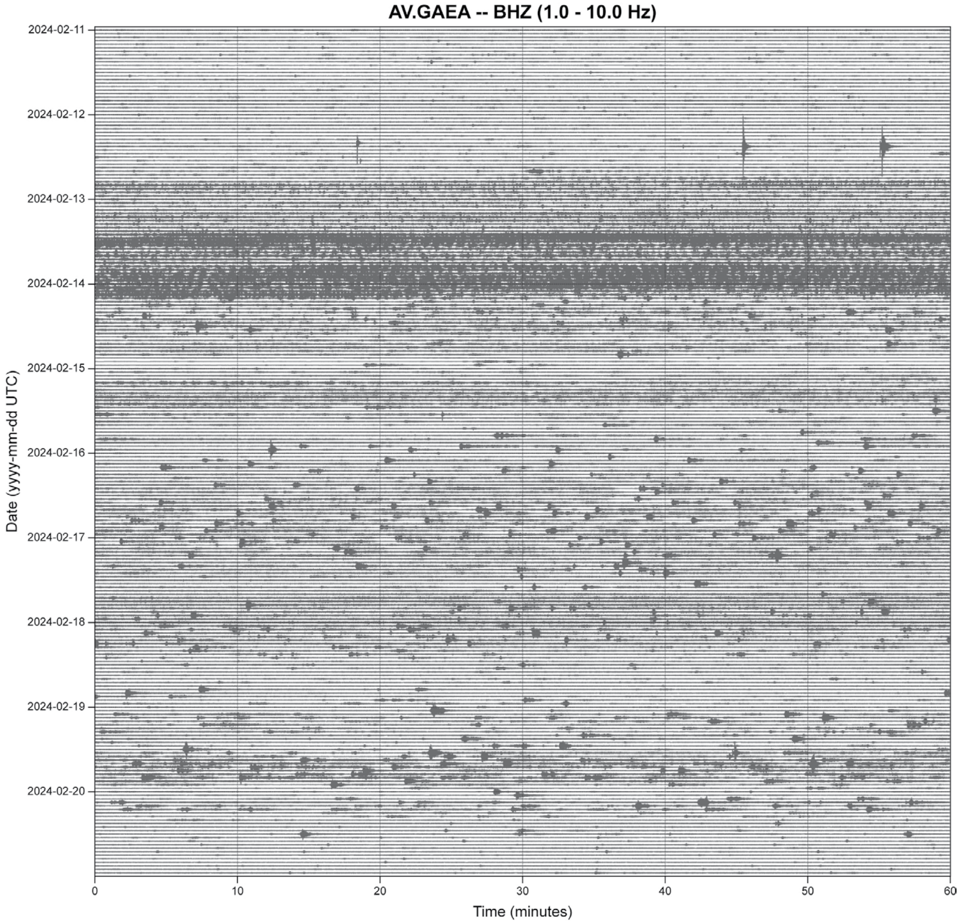

Figure 23. 10-day helicorder of 1-10 Hz filtered seismic data from February 11 through February 21, 2024, recorded at station GAEA. Each row represents 60 minutes of data in time-ascending intervals from top to bottom. Dates are given in year-month-day format.

in infrasound data or in satellite and webcam imagery.

Seismicity waxed and waned at a relatively high level over the following several days (fig. 23), staying well above background until February 20, when seismicity dropped back to its pre-event level. With no further unrest, AVO lowered the Aviation Color Code and Volcano Alert Level to **GREEN** and **NORMAL** on March 5 (table 4). AVO did not detect any subsequent seismicity significantly above background levels throughout the remainder of 2024.

Volcanic Activity in the Commonwealth of the Northern Mariana Islands

Ahyi Seamount

GVP# 284141
20.42°, 145.03°
-79 m
Commonwealth of the Northern Marina Islands
SUBMARINE ERUPTION

Ahyi seamount is a large conical submarine volcano located near the north end of the Commonwealth of the Northern Mariana Islands (fig. 1), about 18 km southeast of the island of Farallon de Pajaros and 600 km north of Saipan Island. The remote location of the seamount has made eruptions difficult to detect, although several have been documented. The most recent submarine eruptive activity prior to

2022 occurred in 2014 and was detected by the regional Commonwealth of the Northern Mariana Islands seismic network and more distant seismic stations, and by hydroacoustic instruments at Wake Island, 2,270 km to the east (Tepp and others, 2019). Submarine explosions during the eruption were also heard and felt by NOAA scuba divers at Farallon de Pajaros, and a multibeam sonar bathymetric survey collected afterward found that a crater about 100 m deep had formed at the summit of the volcano, which had grown to within 79 m of the ocean surface (Tepp and others, 2019).

Recent submarine eruptive activity at Ahyi seamount began again in October 2022 and continued until late March 2023 (fig. 24). This activity was identified by hydroacoustic detections at Wake Island and by plumes of discolored water on the ocean surface visible in high-resolution satellite imagery. After a two-month lull, activity resumed briefly from late May to early June 2023. No further activity was detected until late December 2023, when plumes of discolored water were seen in satellite imagery on December 24 and 31. Curiously, no acoustic detections were recorded on the Wake Island hydroacoustic array in December 2023, so it was uncertain at that time if the plumes were caused by eruptive activity. Detailed descriptions of the volcanic activity observed at Ahyi seamount in 2022 and 2023 are reported in Orr and others (2025) and Nastan and others (in press), respectively.

Because of the uncertainty caused by the lack of hydroacoustic detections, the volcano was kept at **UNASSIGNED** until January 13, 2024, when the Aviation Color Code and Volcano Alert Level were raised to **YELLOW** and **ADVISORY** (table 4, fig. 24). This change was prompted by additional observations of discolored water, including a roughly 10-km-long plume observed in satellite imagery from January 4 and a smaller segmented plume observed in imagery acquired January 10, indicating that a new episode of eruptive activity had begun. Plumes of discolored water were observed frequently in satellite data thereafter through early April, although they became less common starting in March. Many of these plumes were kilometers long—longer than any of those produced in 2022–2023 (fig. 24). Hydroacoustic detections were rare and often ambiguous during this period of activity. This differed markedly from 2022–2023, when definitive hydroacoustic detections from the direction of Ahyi seamount—sometimes hundreds per day—were detected on the Wake Island array (fig. 24), suggesting differences in the style of activity. Although speculative, the activity in 2024 could have been dominantly effusive, while that in 2022 and 2023 may have been more explosive.

With the cessation of visible plumes in early April, the Aviation Color Code and Volcano Alert Level were moved back to **UNASSIGNED** on April 9 (table 4). A plume of discolored water was seen only once over the next several months, in May, indicating activity at the volcano was mostly paused. However, small point-source plumes began to appear again occasionally starting in August (observed retrospectively), presumably marking the gradual onset of another period of more continuous volcanic activity. Distinct plumes of discolored water became especially common at the beginning of November (fig. 25), and the Aviation Color Code and Volcano Alert Level were changed back to **YELLOW** and **ADVISORY** on November 19, 2024 (table 4).

Plumes in the water continued to be seen regularly in satellite data afterward through the end of the year and into 2025. Notably, a whitish material was seen floating on the ocean surface in association with the plumes of discolored water (fig. 25) in several high-resolution satellite images. The material, perhaps foam or a buoyant precipitate, was carried with the current and eventually modified by surface winds into linear streaks, sometimes extending farther downwind than the plumes of discolored water. Similar to the activity in early 2024, hydroacoustic detections from Ahyi seamount during this second period of activity in late 2024 were rare and often ambiguous.

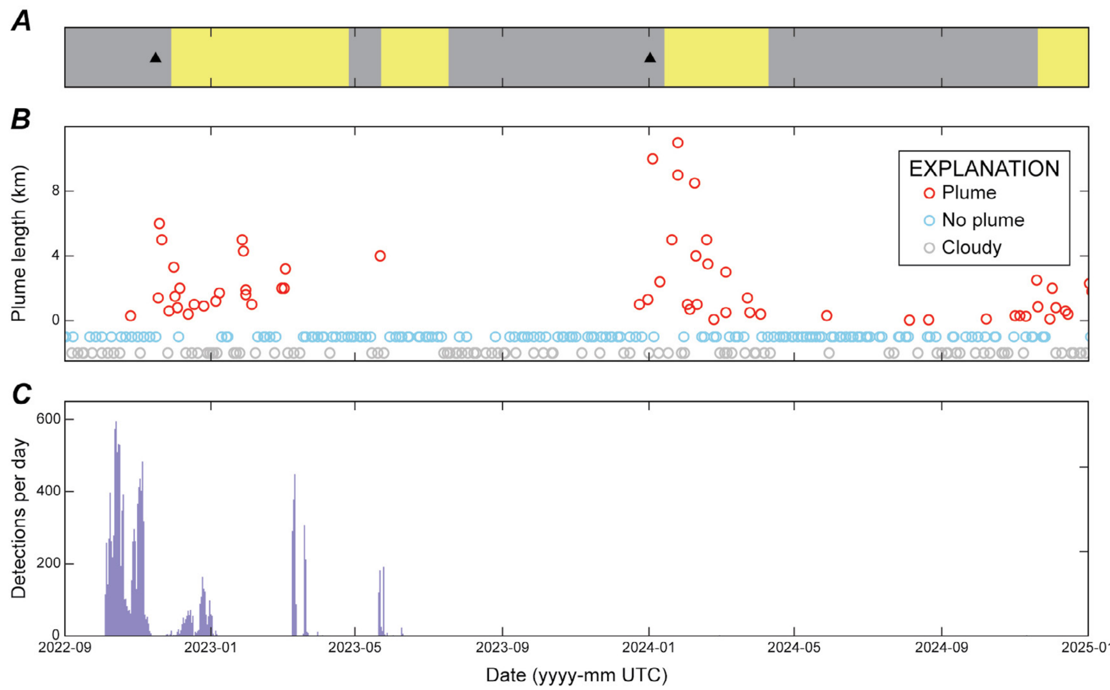

Figure 24. Chronology of volcanic activity at Ahyi seamount from September 2022 through December 2024. A, Color bar timeline showing the Aviation Color Code and Volcano Alert Level (grey is UNASSIGNED, yellow is YELLOW/ADVISORY). Black triangles indicate Information Statements not synchronous with color code and alert level changes. B, Graph showing timeline of plumes of discolored ocean water and plume length observed in high-resolution (Sentinel-2, Landsat, WorldView-1, -2, and -3) satellite data. Cloudy satellite views and clear views without an observable plume are also noted. C, Histogram of hydroacoustic events per day detected by the Wake Island array from the direction of Ahyi seamount. Hydroacoustic signals were detected in late 2023 and 2024 but were too few to register on the graph. Dates are given in year-month format.

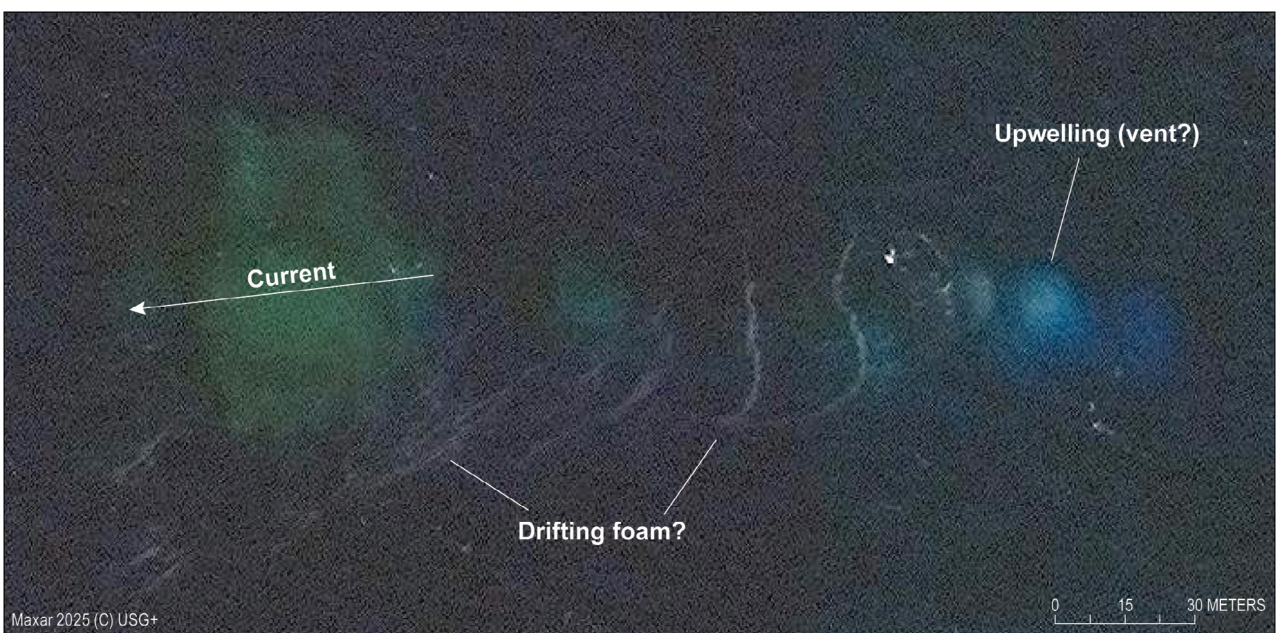

Figure 25. WorldView-3 satellite image showing plume of greenish discolored seawater over Ahyi seamount at 00:51 on November 19, 2024. The area of upwelling is presumed to be directly above the erupting vent. The whitish bands are an unidentified material, possibly foam, originating at the upwelling area and floating on the surface of the water. Surface winds modify the white bands into streaks downwind.

Data availability

The data in this report are made available to the public in accordance with USGS Fundamental Science Practices (https://www.usgs.gov/data-management/overview-data-management). Earthquake data are available through the ANSS Comprehensive Earthquake Catalog (https://earthquake.usgs.gov/data/comcat/), which hosts AVO's earthquake catalog from 2018 onward, and seismic waveform and hydroacoustic data are archived at the EarthScope Consortium SAGE Facility (https://ds.iris.edu/ds/nodes/dmc/). AVO's GNSS data are archived at the EarthScope Consortium GAGE Facility (https://www.unavco.org/data/data.html) under individual DOI assignments for each station time series, which can be found at https://www.unavco.org/data/doi/search/search.html by searching for "AVO". The photographs and webcam images used in this publication are available on the AVO webpage (https://avo.alaska.edu/image/) using search parameters based on the information given in the figure captions.

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Appendix 1. Glossary of Selected Terms and Acronyms

andesite Volcanic rock composed of about 57–63 weight percent silica (SiO_2).

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

basalt Volcanic rock composed of about 45–52 weight percent silica (SiO_2).

basaltic andesite Volcanic rock composed of about 52–57 weight percent silica (SiO_2).

caldera Large, roughly circular depression commonly caused by volcanic collapse.

dacite Volcanic rock composed of about 63–69 weight percent silica (SiO_2).

earthquake swarm Flurry of closely spaced earthquakes or other ground shaking activity; often precedes an eruption.

fumarole Small opening or vent from which hot gases are emitted.

gas emissions General term used to indicate visible (partially condensed) degassing of mixed, and typically unquantified, gas compositions from volcanoes and thermal areas.

Holocene Geologic epoch that extends from the present to about 11,700 years ago.

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

lahar Flow of a mixture of pyroclastic material, sediments and organic ground cover, and water.

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

local magnitude (M_L) Earthquake magnitude scale based on the amplitude of ground motion as measured by a standard seismograph.

long-period earthquake Earthquake with dominant frequency content between 1 and 5 hertz. Used interchangeably with the term low-frequency earthquake.

magma Molten rock below the surface of the Earth.

pyroclast Individual particle ejected during a volcanic eruption; commonly classified by size (for example, ash and lapilli).

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

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

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

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

vent Opening in the Earth's surface through which magma erupts or volcanic gases are emitted.

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

Vulcanian Type of volcanic eruption that ejects material to heights less than about 20 km (12 miles) and lasts on the order of seconds to minutes. They are characterized by discrete, violent explosions, the ballistic ejection of blocks and bombs, atmospheric shock waves, the emission of tephra, and small-scale pyroclastic density currents.