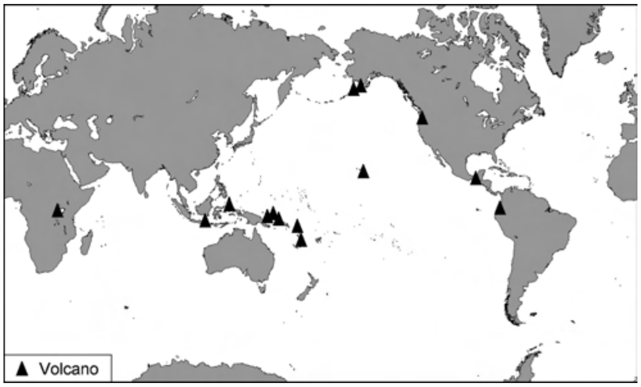
Bulletin of the Global Volcanism Network



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Three Sisters

Oregon, USA
44.10°N, 121.77°W; summit elev. 3,157 m
All times are local (= UTC - 8 hours)

At approximately 1000 on 23 March 2004, a swarm of small earthquakes began at the Three Sisters volcanic center in the central Oregon Cascade Range. As of the morning of 24 March, the regional seismic network had detected ~ 100 earthquakes, with M ~ 1.5; by the end of the swarm, over 300 volcano-tectonic earthquakes with M ~ 1.9 were recorded (figure 1), with the rate of earthquakes peaking late on 23 March. The earthquakes occurred in the NE part of an area centered 5 km W of South Sister volcano, a zone in which the ground had been uplifted by as much as 25 cm since late 1997.

Scientists inferred that the cause of the uplift was continuing magmatic intrusion ~ 7 km below the surface. The intrusion volume was estimated at ~ 40 million cubic meters. Until 23 March, only a few earthquakes had accompanied this process, but scientists predicted that swarms of small earthquakes would eventually accompany the uplift, and they suggested that the most likely cause of the earthquakes was small amounts of slippage on faults as the crust adjusted to the slow ground deformation that had been occurring since 1997. Heat and gases related to the magmatic intrusion also likely caused increases in fluid pressure deep underground, helping trigger minor faulting events.

Scientists deployed another seismometer in order to locate earthquakes more precisely. They also planned additional fieldwork with the assistance of the Willamette and Deschutes National Forests, aiming to fix problems with some field instruments that resulted from a heavy winter snow-pack, and to assess sites for new instruments.

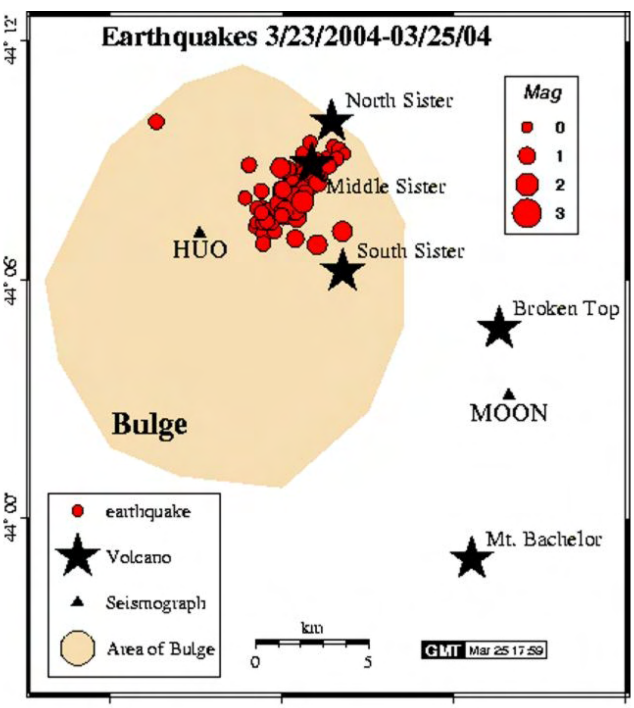

Figure 1. Map of the 23-25 March 2004 seismic swarm at Three Sisters volcanoes. Courtesy of Pacific Northwest Seismograph Network (PNSN) website.

Background. South Sister is the highest and youngest of the Three Sisters volcanoes that dominate the landscape of the central Oregon Cascades. The main edifice of South Sister is constructed of andesitic and dacitic lava flows capped by a symmetrical summit cinder cone of probable latest-Pleistocene age. The late Pleistocene or early Holocene Cayuse Crater on the SW flank of Broken Top volcano and other flank vents such as Le Conte Crater on the SW flank of South Sister mark mafic vents that have erupted at considerable distances from South Sister itself. Late-Holocene eruptions formed a chain of dike-fed rhyodacitic lava domes and flows on the volcano's SE to SW flanks about 2,000 years ago. Satellite radar interferometry (InSAR) obtained by U S Geological Survey scientists detected continuing long-term slight uplift of the ground surface over a broad region centered 5 km west of South Sister volcano that began in 1997.

Information Contacts: *Cascades Volcano Observatory (CVO)*, U.S. Geological Survey (USGS), Building 10, Suite 100, 1300 SE Cardinal Court, Vancouver, WA 98683, (URL: http://vulcan.wr.usgs.gov, http://volcanoes.usgs.gov); *Volcano Hazards Team*, USGS, 345 Middlefield Road, Menlo Park, CA 94025-3591 USA (URL: http://volcanoes.usgs.gov/); *Pacific Northwest Seismograph Network (PNSN)*, University of Washington Geophysics Program, Box 351650, Seattle, WA 98195-1650, USA (URL: http:// www.geophys.washington.edu/SEIS/PNSN/).

Veniaminof

Alaska Peninsula, USA
56.17°N, 159.38°W; summit elev. 2,507 m
All times are local (= UTC - 9 / 8 hours (winter / summer))

After many years of quiescence, Veniaminof began exhibiting increased seismicity during September 2002 along with some possible low-level eruptive activity (*Bulletin* v. 27, no. 10). Variable seismicity contined to be recorded from October 2002 through mid-April 2003 accompanied by steam emissions from the intracaldera cone (*Bulletin* v. 28, nos. 1 and 3). No additional signs of activity were noted until mid-February 2004.

Activity during February 2004. During the week of 15 February 2004, the Alaska Volcano Observatory (AVO) received several reports of small ash clouds rising ~ 30-90 m above the intracaldera cinder and spatter cone of Veniaminof. Residents of Perryville (~ 30 km S) reported a "black puff" of ash on 16 February, followed by strong steam emissions.

A pilot reported a small black ash cloud on 19 February. Satellite imagery from 2310 UTC (1410 AST) on 19 February showed a small, dark trail on the snow leading away from the intracaldera cone, possibly an intra-caldera ash deposit. Aerial photographs on 21 February showed distinct ash deposits (figure 2). No significant seismic activity or thermal anomalies were recorded during the week. Due to the lack of significant seismic activity beneath the volcano, AVO concluded that these small ash clouds were the result of minor explosions caused by the heating of ground water below the intracaldera cone. The Concern Color Code remained at Green.

Satellite imagery on 22 February (figure 3) again showed very localized deposits within the ice-filled caldera. No additional signs of volcanic activity were visible on satellite imagery during 23-27 February, and there were no more reports of ash-plume sightings from observers. Seismicity remained at a low level, and the thermal signature of the intracaldera cone was unchanged from previous months.

Activity during April 2004. During the week of 11 April, several low-level episodes of volcanic tremor and small volcanic earthquakes were recorded. The tremor occurred in pulses lasting several minutes. This represented the strongest seismicity since early 2003 when the Concern Color Code was downgraded from Yellow to Green, although no significant changes in the thermal signature of the intracaldera cone were noted in satellite data.

Perryville residents reported that a steam emission, possibly containing a small amount of volcanic ash, was visible most of the day on 18 April. It became most vigorous at approximately 1730 ADT (0130 UTC on 19 April) when it rose to ~ 460-610 m above the intracaldera cone (~ 2,590-2,740 m altitude). Starting at approximately 1130 ADT on 19 April, tremor and earthquake levels increased, albeit to lower levels than those during the previous week. The Color Code was upgraded to Yellow. During subsequent days in the week of 19 April there was a marked decrease in the episodes of low-level volcanic tremor and small volcanic earthquakes. No emissions were reported.

On the afternoon and evening of 25 April, more than 25 small steam and ash emissions were seen during an 8-hour period, producing clouds that rose ~ 300-610 m above the active cone. During the week of 25 April activity was characterized by small, intermittent ash emissions, low-level volcanic tremor, and small volcanic earthquakes. Small ash emissions were observed during periods of clear weather on 28 April. Ash clouds rose ~ 0.3-1 km above the active cone, and at times were observed drifting for distances of ~ 16 km. Seismic activity fluctuated but remained above background levels.

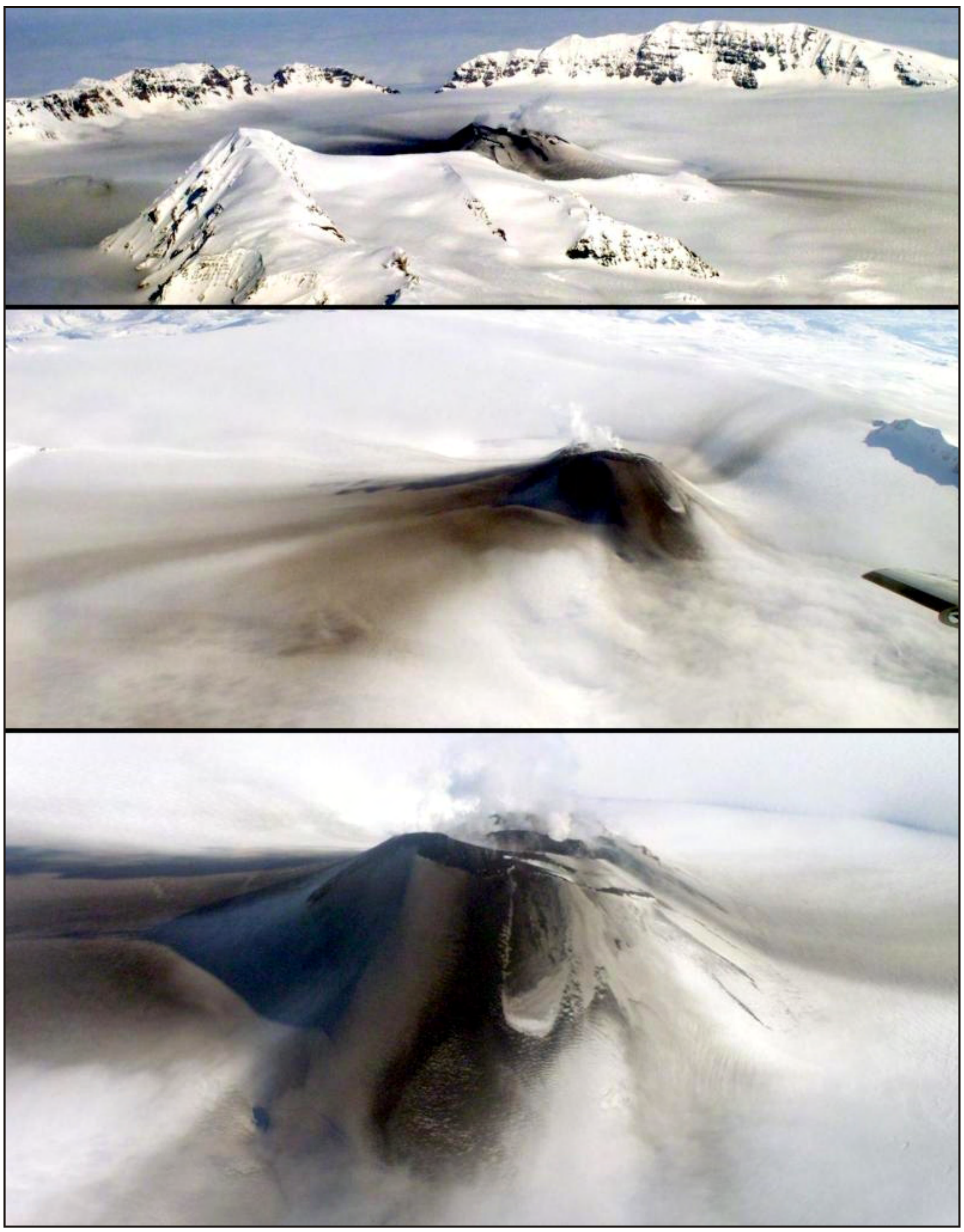

Figure 2. Photographs showing ash deposits in Mount Veniaminof's intracaldera zone taken on 21 February 2004. The top view is from the SW with the Cone Glacier and a caldera rim segment in the left foreground, the intracaldera cone in the center, and the NE caldera rim divided by the Crab Glacier in the background. The close-up photographs of the cone were taken while looking generally SE. Courtesy of Nathan Fratzke and Heidi Breon (Peninsula Airways).

Activity during May 2004. The week of 2 May was characterized by small, intermittent ash emissions, low-level volcanic tremor, and small volcanic earthquakes. Small ash emissions were observed during periods of clear weather on 1-3 May. Ash clouds rose ~ 300-610 m above the active cone. No systematic visual observations of ash plumes were made during 4-18 May due to the camera-monitoring system being repaired, though residents reported continued activity on 5 May. However, the observed seismicity was similar to that recorded in the previous week, suggesting that ash emissions continued. Satellite imagery showed ash deposits on the snow to distances of ~ 8 km from the vent, and a pilot reported ash as far as 33 km from the cone.

There were no observations of ash emissions during the week of 9 May, when cloudy conditions obscured the volcano. Seismic activity was more intermittent and lower in amplitude than in previous weeks; however, seismicity suggested that ash emissions occasionally occurred. Unrest during the week of 16 May was characterized by moderate levels of intermittent volcanic tremor, which was similar to the seismic

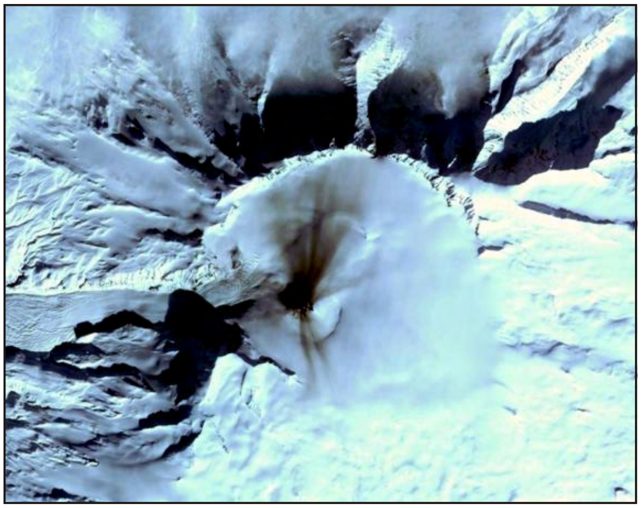

Figure 3. Image of Veniaminof from the Terra ASTER 15-m satellite (bands 3, 2, and 1) acquired on 22 February 2004 at 2158 UTC (1258 local time). This close-up view shows several ash bands in different directions suggesting multiple small ash eruptions with visible deposits largely confined within the 8- to 11-km-diameter caldera walls. Courtesy of AVO.

signals recorded in association with the small ash emissions of 25 and 28 April and 1-3 May. On 18 May, a pilot reported an ash plume rising 300-900 m above the volcano's summit (2.8-3.4 km altitude) and extending ~32 km NE. Cloudy conditions obscured observation by satellite.

Bursts of volcanic tremor continued during the week of 24 May. Activity in general was lower than that of the previous week, but sequences of tremor accompanying ash emissions continued to be observed. Clear views of the volcano on 26 May showed weak steam and low ash emissions emanating from the intracaldera cone. Most of these emissions did not rise higher than the active cone (2,507 m elevation). Satellite data acquired on 26 May showed ash deposits in the N and SE portions of the caldera. The only significant ash emissions observed during the week of 31 May occurred the evening of 30 May into the morning of 31 May; none appeared to have exceeded 3,000 m altitude. Clear views earlier on 30 May showed steam emissions from near the base of the intracaldera cone, which rarely rose above the top of the cone. No activity was observed in satellite data as the volcano was largely obscured by clouds.

Activity during June 2004. Bursts of volcanic tremor continued throughout June, and were thought to be indicative of small, low-level ash emissions. Clouds obscured the volcano for most of the month, making observations difficult. The only ash emissions observed in the week of 7 June occurred the evening of 11 June. None appeared to have exceeded 3,000 m altitude. On 16 June at 2350, a pilot observed an ash cloud that rose ~ 2,650 m altitude. This ash cloud was also observed in satellite imagery. Low-level activity continued during the week of 28 June, with episodes of low-level tremor and small volcanic earthquakes occurring regularly on 30 June. Observations made by AVO during an aerial overflight of the active cone on 27 June indicated small amounts of dark ash on the surface of the snow within the ice-and-snow-filled caldera. The ash, although apparently thin, covered most of the snow surface inside the caldera.

Background. Massive Veniaminof volcano, one of the highest and largest volcanoes on the Alaska Peninsula, is truncated by a steep-walled, 8 x 11 km, glacier-filled caldera that formed around 3700 years ago. The caldera rim is up to 520 m high on the north, is deeply notched on the west by Cone Glacier, and is covered by an ice sheet on the south. Post-caldera vents are located along a NW-SE zone bisecting the caldera that extends 55 km from near the Bering Sea coast, across the caldera, and down the Pacific flank. Historical eruptions probably all originated from the westernmost and most prominent of two intra-caldera cones, which reaches an elevation of 2156 m and rises about 300 m above the surrounding icefield. The other cone is larger, and has a summit crater or caldera that may reach 2.5 km in diameter, but is more subdued and barely rises above the glacier surface.

Information Contacts: *Alaska Volcano Observatory (AVO)*, a cooperative program of a) *U.S. Geological Survey*, 4200 University Drive, Anchorage, AK 99508-4667, USA (URL: http://www.avo.alaska.edu/; Email: tlmurray@usgs.gov), b) *Geophysical Institute, Univ. of Alaska*, P.O. Box 757320, Fairbanks, AK 99775-7320, USA (Email: eich@dino.gi.alaska.edu), and c) *Alaska Division of Geological & Geophysical Surveys*, 794 University Ave., Suite 200, Fairbanks, AK 99709, USA (Email: cnye@giseis.alaska.edu).

Shishaldin

Aleutian Islands
54.756°N, 163.97°W; summit elev. 2,857 m
All times are local (= UTC - 9 / 8 hours (winter / summer))

The last report on Shishaldin (*Bulletin* v. 27, no. 5) described an increase in backround seismicity in mid-May 2002. Specifically, there was an increase in shallow low-frequency earthquakes and several tremor-like signals. However, because there were no thermal anomolies visible on satellite imagery, and no reports of anomalous volcanic activity, Shishaldin remained at Concern Color Code Green.

Activity during August 2002. On 16 August 2002, the Alaska Volcano Observatory (AVO) received notification of a pilot report, via the National Weather Service (NWS) Alaska Aviation Weather Unit (AAWU), of volcanic activity. The pilot report indicated that Shishaldin appeared to be erupting, producing steam and dark clouds to 3.2 km altitude that moved to the NW-SE. A NWS observer in Cold Bay, ~ 100 km E of the volcano, reported a steam-rich plume coming from Shishaldin. As per operating policy, the AAWU issued an "eruption SIGMET" advising the aviation community of the possibility of airborne volcanic ash. Upon receiving the pilot report, the AVO immediately analyzed seismic and satellite data and determined that Shishaldin was at a normal background state and had not erupted. Further discussions with the observer in Cold Bay indicated that the steam plume was not uncommon. The last significant ash-producing eruptions of Shishaldin occurred during April-May 1999. Since that time, low-frequency seismic events and occasional steam plumes have characterized activity at the volcano. Shishaldin remained at Concern Color Code Green.

Activity during April-May 2004. The AVO raised the Concern Color Code at Shishaldin from Green to Yellow on 3 May due to unusual seismicity during the previous week. Seismicity changed from discrete earthquakes to more continuous ones, and tremor was observed for the first time since the most recent eruption ended in May 1999. Airwaves (acoustical waves traveling in air) accompanying earthquakes were recorded by the seismic network, suggesting that the source of seismicity had become more shallow. Satellite data showed no significant increase in ground temperature, nor had there been reports of increased steaming. However, AVO warned that activity at Shishaldin could increase rapidly and increased the frequency of their seismic-data analysis.

Seismic unrest continued during 30 April to 7 May, and was characterized by sequences of volcanic earthquakes and seismic tremor. The number of airwaves recorded by the seismic network diminished in comparison to the previous week, with weaker signals recorded.

Thermal anomalies at the summit were observed on satellite imagery under optimal viewing conditions. Retrospective analysis confirmed that these data, as well as similar signals observed in January 2004, were the first observed since August 2000. AVO saw no signs that an eruption was imminent. Shishaldin remained at Concern Color Code Yellow throughout the month.

During 8-14 May seismic unrest continued, characterized by sequences of volcanic earthquakes, small explosions, and seismic tremor. A weak thermal anomaly observed at the summit on 11 May was similar to those detected occasionally since January 2004. On 16 May, a pilot reported an ash plume that rose ~ 300 m above the volcano's summit. Satellite imagery from 17 May (figure 4) showed a vigorous plume, possibly containing small amounts of ash, emanating from the summit. Seismic unrest during 14-21 May was characterized by weak seismic tremor and small explosions, and during 21-28 May also included occasional discrete low-frequency earthquakes. In addition, small explosion signals were recorded by a pressure sensor. Meteorological clouds obscured views of the volcano. Satellite data acquired at 0823 UTC (0023 ADT) on 29 May showed that the crater to continue to be warmer than background temperatures.

Activity during June-July 2004. Seismic unrest continued during 18 June-2 July, characterized by weak seismic tremor and occasional discrete low-frequency earthquakes. At roughly 0800 ADT on 24 June, pilots reported steam rising at least 100 m above Shishaldin's cone. Around that time, a possible weak thermal anomaly was visible on satellite imagery. Shishaldin remained at Concern Color Code Yellow.

Background. The beautifully symmetrical volcano of Shishaldin is the highest and one of the most active volcanoes of the Aleutian Islands. The 2,857-m-high, glacier-covered volcano is the westernmost of three large stratovolcanoes along an E-W line in the eastern half of Unimak Island. The Aleuts named the volcano Sisquk, meaning "mountain which points the way when I am lost." A steady steam plume rises from its small summit crater. Constructed atop an older glacially dissected volcano, Shishaldin is Holocene in age and largely basaltic in composition. Remnants of an older ancestral volcano are exposed on the west and NE sides at 1,500-1,800 m elevation. Shishaldin contains over two dozen pyroclastic cones on its NW flank, which is blanketed by massive aa lava flows. Frequent explosive activity, primarily consisting of strombolian ash eruptions from the small summit crater, sometimes producing lava flows, have been recorded since the 18th century.

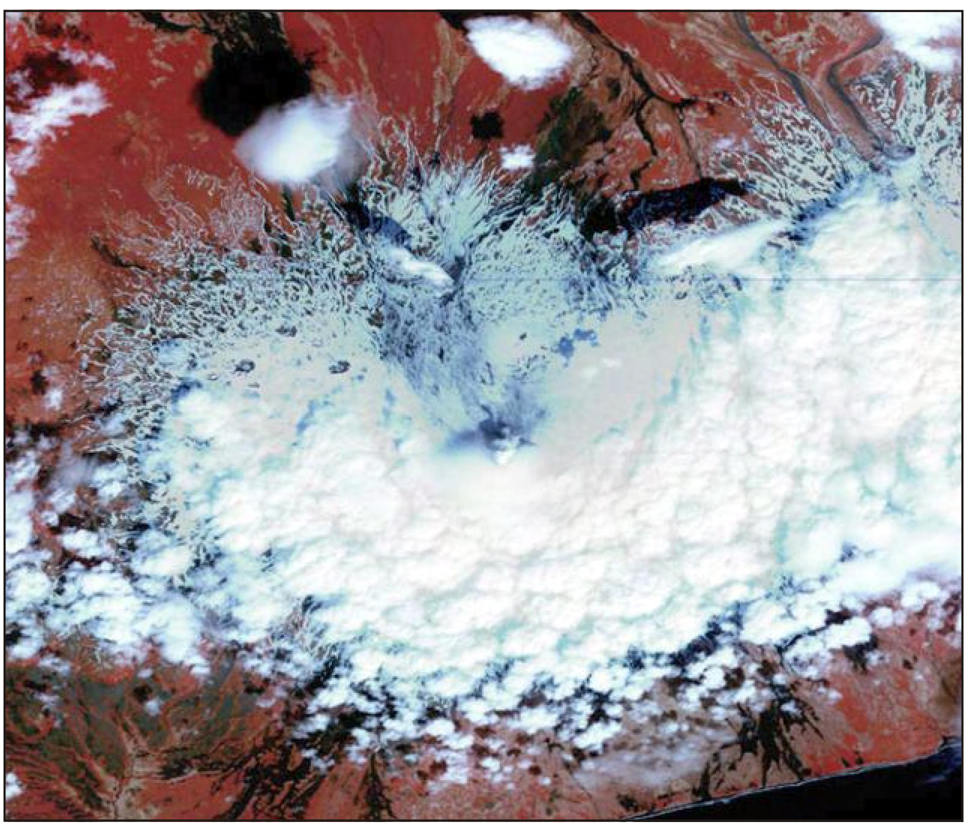

Figure 4. Shishaldin as depicted by an ASTER false color (image with bands 3, 2, and 1 as RGB and cloud/plume detail added with a semi-transparent band 4) taken 17 May 2004. The summit crater is shrouded by clouds, but a small plume that appears to contain ash is blowing toward the N. Dark streaks on the northern flanks may be partly from a light dusting of ash; however, other dark streaks appear as darker features melting through the snow. Courtesy of AVO.

Information Contact: *Alaska Volcano Observatory (AVO)*, a cooperative program of (a) *U.S. Geological Survey*, 4200 University Drive, Anchorage, AK 99508-4667 USA (Email: tkeith@tundra.wr.usgs.gov; URL: http://www.avo.alaska.edu), (b) *Geophysical Institute, University of Alaska*, P.O. Box 757320, Fairbanks, AK 99775-7320 USA (Email: eich@dino.gi.alaska.edu), and (c) *Alaska Division of Geological & Geophysical Surveys*, 794 University Ave., Suite 200, Fairbanks, AK 99709 USA (Email: cnye@giseis.alaska.edu).

Kilauea

Hawaii, USA
19.425°N, 155.292°W; summit elev: 1,222 m
All times are local (= UTC - 10 hours)

During mid-2004 lava flows erupting from Kilauea once again began reaching the ocean, where they slowly added new land to the SE coast of Hawai`i Island (figure 5). Lava began spilling into the ocean on 30-31 May 2004. Nearly a year before that, on 9 July 2003, the lava tube system feeding flows to the ocean ceased carrying lava, which instead escaped in a series of breakouts and numerous surface flows between the Pu`u `O`o vent and the coast. Hundreds of breakouts occurred between July 2003 and May 2004 within ~ 5 km of the vent.

One of these flows, termed the Banana flow (see figure 5), started to advance down Pulama pali in April 2004. The Banana flow developed from breakouts from part of the Mother's Day lava tube, centered near the former Banana Tree kipuka (an "island" of undisturbed land completely surrounded by one or more lava flows). The breakouts became prominent in the middle of April, and lava started down Pulama pali shortly thereafter. The Banana Flow eventually reached the coastal flat on 2 May. It took nearly a month for the Banana flow to creep across the flat and enter the sea off Wilipe`a lava delta on 30 May. Interaction of the lava and water was not explosive. A spectacular set of photos of lava pouring into the ocean at this time appears on the Hawaiian Volcano Observatory website (figure 6, for example).

Figure 6. Lava entering the ocean on 23 July 2004 at the Wilipe'a delta. As waves broke upon the delta, the lowermost entry points of the advancing lava became totally submerged and quenched, forming a dark crust. As the water receded, the crust ruptured and molten lava spilled out. This cycle continued with each incident wave. Courtesy U.S. Geological Survey Hawaiian Volcano Observatory.

On 13 June, two collapses occurred at Kilauea's lava delta along its W sector, sending sizable chunks of the delta into the sea (figure 7). On 14 June, most lava was being supplied to the ocean through lava tubes, but several surface lava flows were visible on the delta and traveling down the old sea cliff behind the Wilipe`a delta. The larger eastern part of the lava delta had several active lava entries into the ocean, in general larger than those on the western part of the delta. All vents were active in the crater of Pu`u `O`o.

Since March 2004, very weak background tremor continued at Kilauea's summit along with a few long-period earthquakes. Tremor at Pu`u `O`o remained at its typical moderate levels through early June 2004, after which some higher levels were observed. Several episodes of inflation and deflation occurred during this time. One deflation-inflation event began 20 March and culminated 23 March with lava emerging from the S base of Pu`u `O`o cone. A weak swarm of low-frequency earthquakes and a 2-hour period of moderate-to-strong volcano tectonic earthquakes were recorded during 24-25 March.

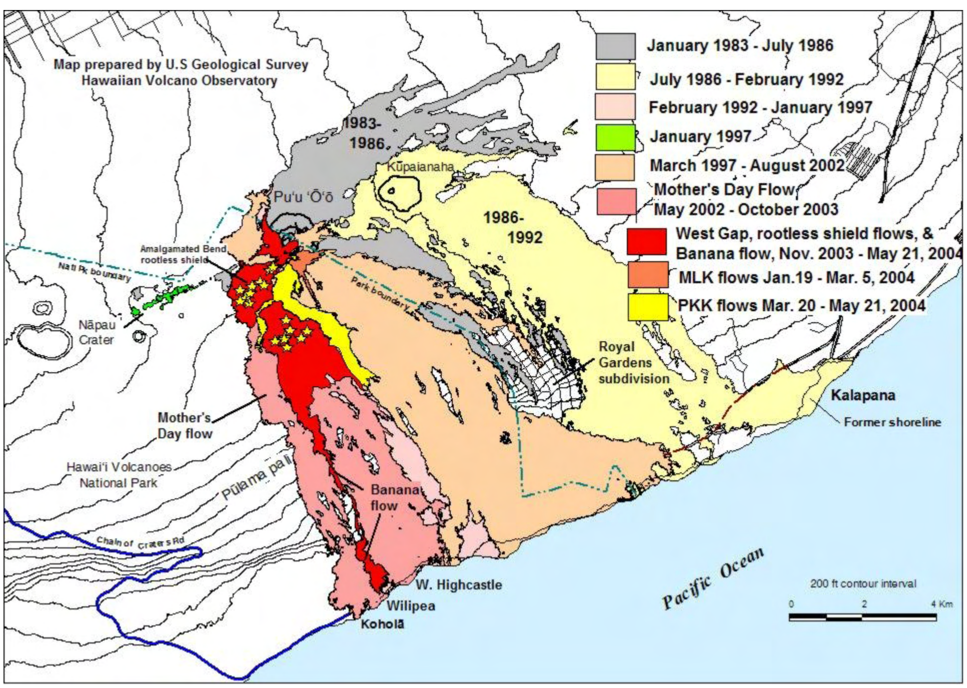

Figure 5. Map of lava flows on the S coastal part of Kilauea as of 21 May 2004. The key at the right distinguishes 9 map units, lava flows erupted at various times. The Mother's Day flow began erupting on 12 May 2002 and continues to the present. More recent lava flows that erupted in November 2003 through 21 May 2004 included the Banana flow (labeled), which developed gradually, starting in the middle of April 2004. Stars indicate centers of formerly active, but now dead, rootless shields that formed along one or more lava tubes in the Mother's Day flow. The Kuhio flow (named for Prince Kuhio Kalaniana`ole and abbreviated on the map as PKK), was active most of the time from 20 March to 21 May 2004. As of May 21, most activity was located S of the rootless shield complex in the Banana flow. Courtesy U.S. Geological Survey Hawaiian Volcano Observatory.

Background. Kilauea volcano, which overlaps the east flank of the massive Mauna Loa shield volcano, has been Hawaii's most active volcano during historical time. Eruptions of Kilauea are prominent in Polynesian legends; written documentation extending

Figure 7. Aerial view on 23 July of the eastern part of the Banana flow lava delta, looking W. Streams of molten lava enter the ocean in the lower center part of the photo. The patchwork pattern on the delta partly results from numerous surface breakouts of lava from tubes during several previous days. A rope barrier cuts across the photo's upper right-hand corner. The barrier marks the limit of visitor access to the delta for their safety. Courtesy U.S. Geological Survey Hawaiian Volcano Observatory.

back to only 1820 records frequent summit and flank lava flow eruptions that were interspersed with periods of long-term lava lake activity that lasted until 1924 at Halemaumau crater, within the summit caldera. The 3 x 5 km caldera was formed in several stages about 1500 years ago and during the 18th century; eruptions have also originated from the lengthy East and SW rift zones, which extend to the sea on both sides of the volcano. About 90% of the surface of the basaltic shield volcano is formed of lava flows less than about 1100 years old; 70% of the volcano's surface is younger than 600 years. A long-term eruption from the East rift zone that began in 1983 has produced lava flows covering more than 100 sq km, destroying nearly 200 houses and adding new coastline to the island.

Information Contact: *Hawaiian Volcano Observatory (HVO)*, U.S. Geological Survey, Hawaii Volcanoes National Park, P.O. Box 51, Hilo, HI 96718, USA (URL: http://hvo.wr.usgs.gov/; Email: hvo-info@hvo-mail.wr.usgs.gov).

Yasur

Vanuatu
19.52°S, 169.425°E; summit elev. 361 m

Activity consistently identified in MODVOLC thermal alerts through most of 2002 (*Bulletin* v. 28, no. 1) continued to 4 June 2003, but at lower levels (figure 8). There was usually only one alert pixel on each detection, barely above the detection threshold, with the highest alert ratio of -0.74. After a brief respite, activity was detected several times during 17 September through October 2003. No subsequent activity was detected until 15 March, 10 April, and 28 May 2004. These three alerts each triggered one alert pixel and had low alert ratios, about -0.8, just above the detection threshold. It seems likely that activity continued throughout the period, but was below the MODVOLC threshold most of the time and did not trigger an alert. There were no other reports of activity for this period.

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. Yasur, the best-known and most frequently visited of the Vanuatu volcanoes, has been in more-or-less continuous strombolian and vulcanian activity since Captain Cook observed ash eruptions in 1774. This style of activity may have continued for the past 800 years. Yasur, located at the SE tip of Tanna Island, is a mostly unvegetated 361-m-high pyroclastic cone with a nearly circular, 400-m-wide summit crater. Yasur is largely contained within the small Yenkahe caldera and is the youngest of a group of Holocene volcanic centers constructed over the down-dropped NE flank of the Pleistocene Tukosmeru volcano. Active tectonism along the Yenkahe horst accompanying eruptions of Yasur has raised Port Resolution harbor more than 20 m during the past century.

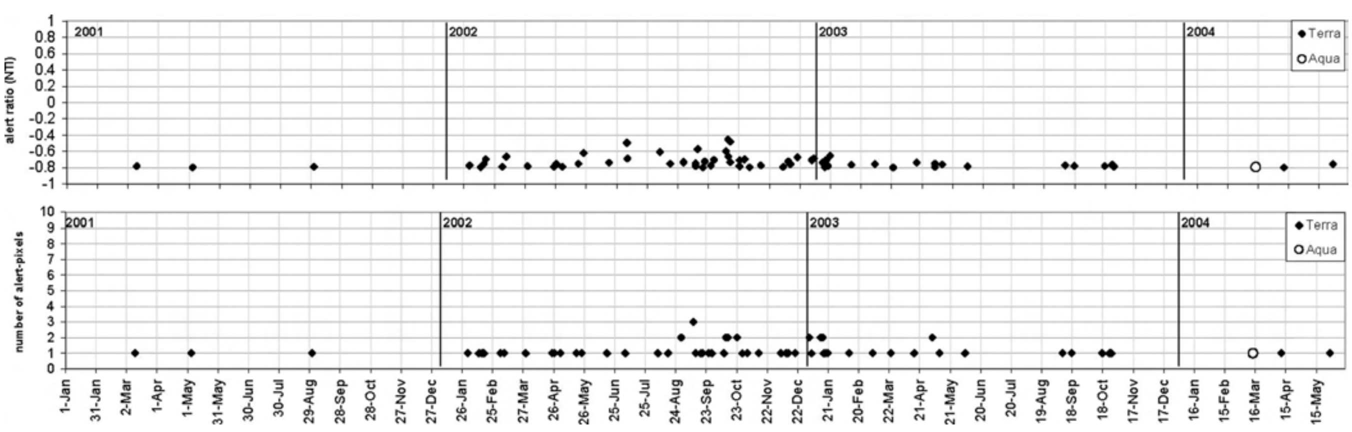

Figure 8. MODIS thermal alerts from Yasur for 1 January 2001-31 May 2004. Thermal alerts collated by Charlotte Saunders and David Rothery; data courtesy of the Hawaii Institute of Geophysics and Planetology's MODIS thermal alert team.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, Department of Earth Sciences, The Open University, Milton Keynes, MK7 6AA, United Kingdom (Email: d.a.rothery@open.ac.uk).

Lopevi

Vanuatu
16.507°S, 168.346°E; summit elev. 1,413 m
All times are local (= UTC + 11 hours)

Subsequent to the events of June 2001 (*Bulletin* v. 28, no. 1) only one further period of activity, between 9 and 16 June 2003, was indicated by MODVOLC. MODIS detected activity on 9 June 2003 first with Terra at 1135 UTC with six alert pixels, followed by Aqua at 1435 UTC, when the alert pixels had reduced in number to four. The highest alert ratio, +0.432 (unusually high) was detected by the Aqua satellite on 13 June 2003. There were three days when the number of alert pixels reached six (on 9, 13, and 16 June 2003). These data suggested that a lava flow, previously noted as occurring on 14 June 2003 (*Bulletin* v.28, no. 6), probably began effusion at least as early as 9 June.

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. The small 7-km-wide conical island of Lopevi is one of Vanuatu's most active volcanoes. A small summit crater containing a cinder cone is breached to the NW and tops an older cone that is rimmed by the remnant of a larger crater. The basaltic-to-andesitic volcano has been active during historical time at both summit and flank vents, primarily along a NW-SE-trending fissure that cuts across the island, producing moderate explosive eruptions and lava flows that reached the coast. Historical eruptions at the 1,413-m-high volcano date back to the mid-19th century. The island was evacuated following eruptions in 1939 and 1960. The latter eruption, from a NW-flank fissure vent, produced a pyroclastic flow that swept to the sea and a lava flow that formed a new peninsula on the western coast.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Ambrym

Vanuatu
16.25°S, 168.12°E; summit elev. 1334 m
All times are local (= UTC + 11 hours)

Ambrym triggered continued alerts during 2003 and 2004 at both Marum and Benbow craters, with Marum alerts being the slightly more common (figures 9 and 10). Activity appeared less intense than in previous years, but more alerts were issued due to the availability of Aqua data starting from January 2004. The highest alert ratio (-0.088) (see *Bulletin* v. 28, no. 1 for a discussion of the alert ration) was detected by Aqua on 14 May 2004 and the highest number of alert pixels detected for any one pass was four, a situation repeated on 29 June, 21 August, and 2 November 2003. Visual observations during September 2003 (*Bulletin* v. 28, no. 9) confirmed that there was activity at these craters.

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. Ambrym, a large basaltic volcano with a 12-km-wide caldera, is one of the most active volcanoes of the New Hebrides arc. A thick, almost exclusively pyroclastic sequence, initially dacitic, then basaltic, overlies lava flows of a pre-caldera shield volcano. The caldera was formed during a major plinian eruption with dacitic pyroclastic flows about 1900 years ago. Post-caldera eruptions, primarily from Marum and Benbow cones, have partially filled the caldera floor and produced lava flows that ponded on the caldera floor or overflowed through gaps in the caldera rim. Post-caldera eruptions have also formed a series of scoria cones and maars along a fissure system oriented ENE-WSW. Eruptions have apparently occurred almost yearly during historical time from cones within the caldera or from flank vents. However, from 1850 to 1950, reporting was mostly limited to extra-caldera eruptions that would have affected local populations.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Tinakula

Solomon Islands
10.38°S, 165.80°E; summit elev. 851 m

Inspection of Terra MODIS day- and night-time data (i. e. original data, rather than the thresholded alert data on the MODVOLC website) for 2001 and 2002 identified cloud-free intervals over Tinakula during January-April 2001, August-September 2001, January 2002, and August-September 2002. MODVOLC thermal alerts were previously reported for 15 January, 6 March, and 16 April 2001 (*Bulletin* v. 28, no. 1). Recognizable thermal anomalies not noted earlier by the automated system appeared at night on 10 January 2001 (alert ratio, –0.804), and during the day on 25 January 2001 (alert ratio, –0.790). This new information reinforces the interpretation that small-scale activity was occurring during the January-April 2001 time period.

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the

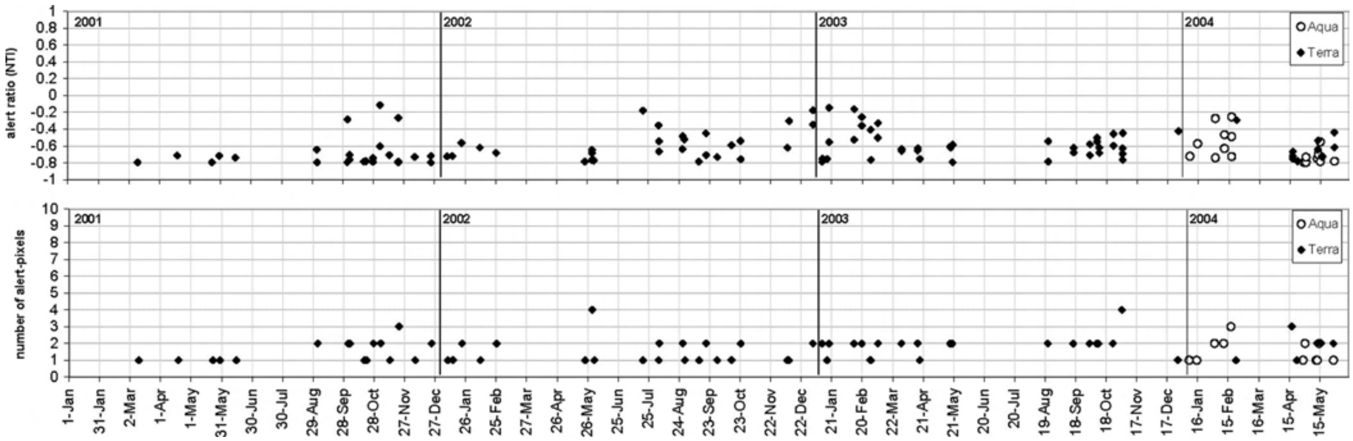

Figure 9. MODVOLC thermal alerts from Benbow crater at Ambrym, 1 January 2001-31 May 2004. Thermal alerts collated by Charlotte Saunders and David Rothery; data courtesy of the Hawaii Institute of Geophysics and Planetology's MODIS thermal alert team.

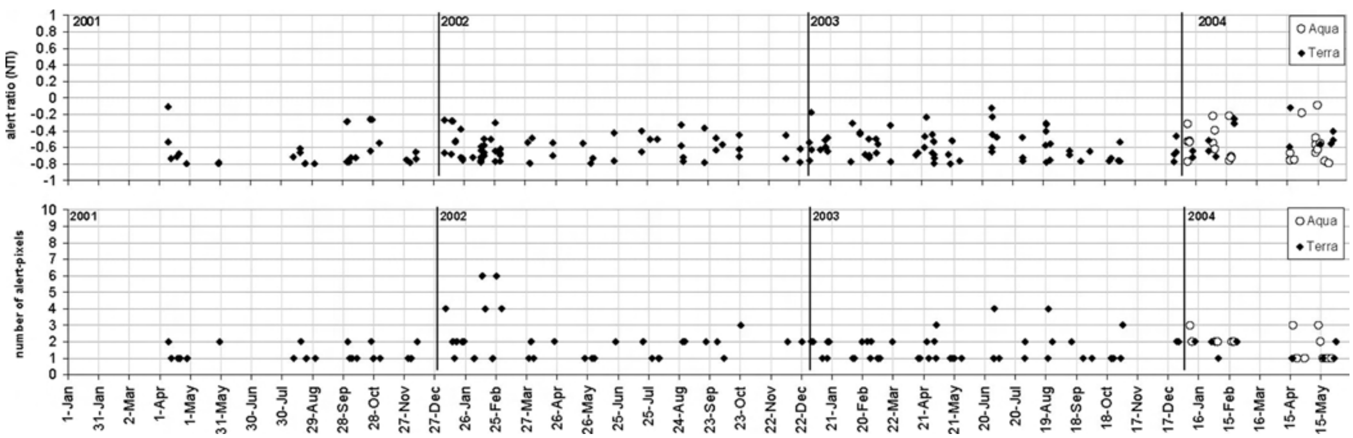

Figure 10. MODVOLC thermal alerts from Marum crater at Ambrym, 1 January 2001-31 May 2004. Thermal alerts collated by Charlotte Saunders and David Rothery; data courtesy of the Hawaii Institute of Geophysics and Planetology's MODIS thermal alert team.

MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. The small 3.5-km-wide island of Tinakula is the exposed summit of a massive stratovolcano that rises 3-4 km from the sea floor at the NW end of the Santa Cruz islands. Tinakula resembles Stromboli volcano in containing a breached summit crater that extends from the 851-m-high summit to below sea level. Landslides enlarged this scarp in 1965, creating an embayment on the NW coast. The satellitic cone of Mendana is located on the SE side. The dominantly andesitic Tinakula volcano has frequently been observed in eruption since the era of Spanish exploration began in 1595. In about 1840, an explosive eruption apparently produced pyroclastic flows that swept all sides of the island, killing its inhabitants. Frequent historical eruptions have originated from a cone constructed within the large breached crater. These have left the upper flanks of the volcano and the steep apron of lava flows and volcaniclastic debris within the breach unvegetated.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Bagana

Papua New Guinea

6.140°S, 155.195°E; summit elev. 1,750 m

MODVOLC alerts occurred at the same rate as in 2001-2002 (*Bulletin* v. 28, no. 1), with quasi-continuous alerts from January 2003 to May 2004 (figure 11). These were mostly one- or two-pixel alerts with an average alert ratio of -0.712. On 21 July 2003 activity appeared to have intensified, with an alert ratio of -0.328 and three alert pixels detected. By 13 August 2003 activity was back to 'normal' levels. Then on 18 April 2004, activity picked up again, with a maximum alert ratio for this period of -0.135, along with a maximum number of four alert pixels on 22 April (Aqua satellite) and 6 May 2004 (Terra satellite).

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.

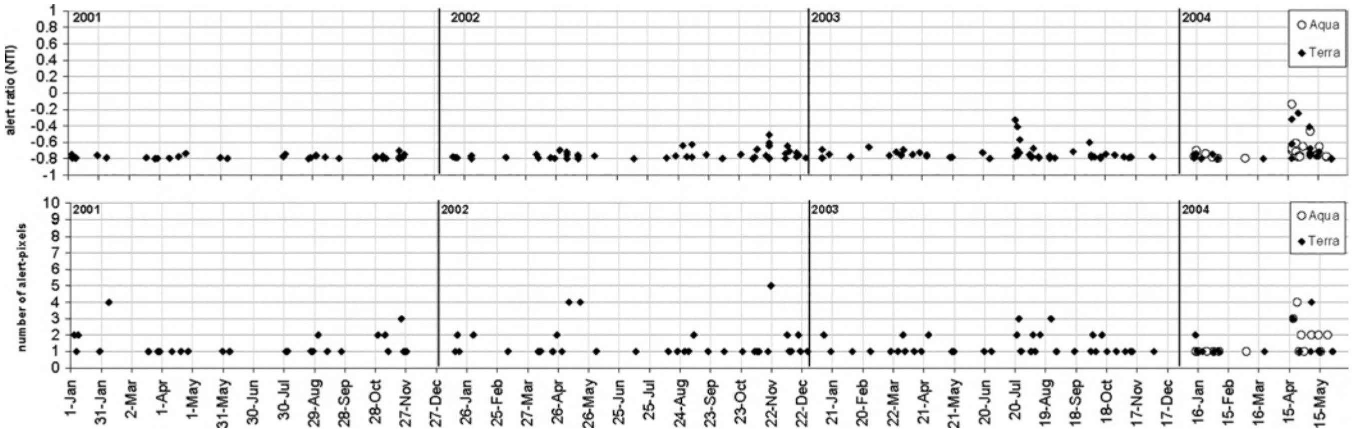

Figure 11. MODIS thermal alerts from Bagana for 1 January 2001-31 May 2004. Thermal alerts collated by Charlotte Saunders and David Rothery; data courtesy of the Hawaii Institute of Geophysics and Planetology's MODIS thermal alert team.

edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. Bagana volcano, occupying a remote portion of central Bougainville Island, is one of Melanesia's youngest and most active volcanoes. Bagana is a massive symmetrical lava cone largely constructed by an accumulation of viscous andesitic lava flows. The entire lava cone could have been constructed in about 300 years at its present rate of lava production. Eruptive activity at Bagana is characterized by non-explosive effusion of viscous lava that maintains a small lava dome in the summit crater, although explosive activity occasionally producing pyroclastic flows also occurs. Lava flows form dramatic, freshly preserved tongue-shaped lobes up to 50-m-thick with prominent levees that descend the volcano's flanks on all sides.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Rabaul

Papua New Guinea
4.271°S, 152.203°E; summit elev. 688 m

MODVOLC alerts were still intermittent adjacent to the site of the Tavurvur cone up to the end of April 2003, with single alert pixels detected on 8 January, 31 March, and 30 April 2003 (figure 12). This was consistent with earlier reports of ground-based observations (*Bulletin* v. 28, no. 3 and v. 28, no. 9), which described sub-continuous ash emissions for this period. Although there were frequent ash eruptions during March-October 2003 (*Bulletin* v. 28, no. 9), no alerts were generated by MODVOLC.

MODVOLC detection started again on 12 October 2003, when three alert pixels were recorded. Alerts were numerous through October-December 2003, concluding with six single-pixel alerts, with the last occurring on 25 January 2004. The highest alert ratio was -0.57, seen on 16 October 2003, but most of the alerts for this period were just above the detection threshold. This was consistent with previously reported observations (*Bulletin* v. 28, no. 11), al-

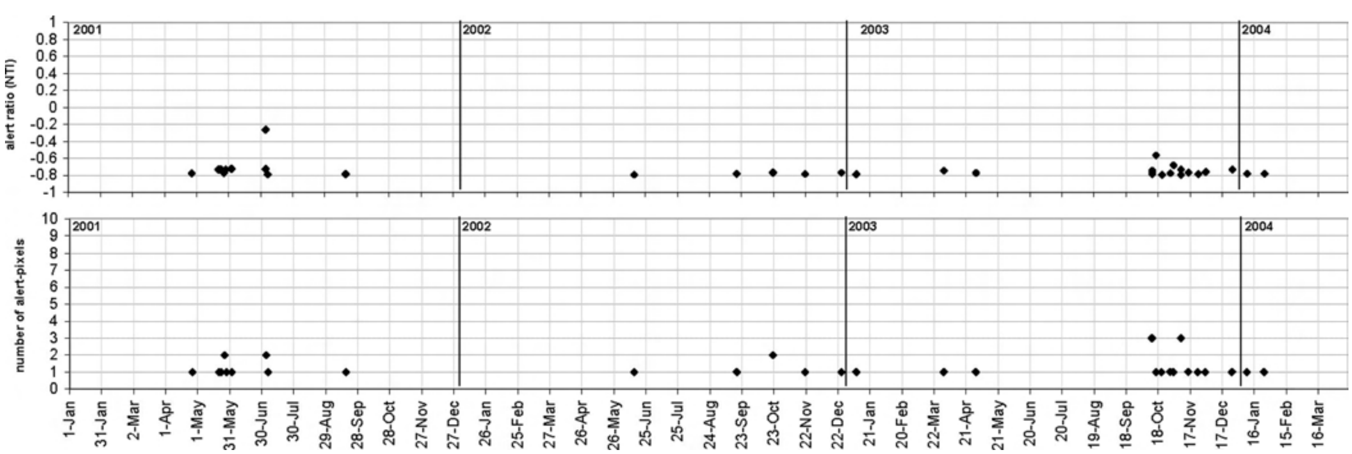

Figure 12. MODIS thermal alerts from Rabaul's Tavurvur cone seen during 1 January 2001–31 May 2004. Thermal alerts collated by Charlotte Saunders and David Rothery; data courtesy of the Hawaii Institute of Geophysics and Planetology's MODIS thermal alert team.

though there were no ground-based observational reports of higher activity for 12-16 October when the alerts appeared most intense.

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. The low-lying Rabaul caldera on the tip of the Gazelle Peninsula at the NE end of New Britain forms a broad sheltered harbor utilized by what was the island's largest city prior to a major eruption in 1994. The outer flanks of the 688-m-high asymmetrical pyroclastic shield volcano are formed by thick pyroclastic-flow deposits. The 8 x 14 km caldera is widely breached on the east, where its floor is flooded by Blanche Bay and was formed about 1,400 years ago. An earlier caldera-forming eruption about 7,100 years ago is now considered to have originated from Tavui caldera, offshore to the north. Three small stratovolcanoes lie outside the northern and NE caldera rims of Rabaul. Post-caldera eruptions built basaltic-to-dacitic pyroclastic cones on the caldera floor near the NE and western caldera walls. Several of these, including Vulcan cone, which was formed during a large eruption in 1878, have produced major explosive activity during historical time. A powerful explosive eruption in 1994 occurred simultaneously from Vulcan and Tavurvur volcanoes and forced the temporary abandonment of Rabaul city.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Ulawun

Papua New Guinea
5.05°S, 151.33°E; summit elev. 2,334 m

No new activity was detected by MODVOLC as recently as mid-2004. This was the case despite reports of seismic activity and deflation during January-March 2003 (*Bulletin* v. 28, no. 3), as well as white vapor emissions and offshore effervescence (*Bulletin* v. 28, no. 9) and intermittent ash plumes during September-December 2003 (*Bulletin* v. 28, no. 11).

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. The symmetrical basaltic-to-andesitic Ulawun stratovolcano is the highest volcano of the Bismarck arc, and one of Papua New Guinea's most frequently active. Ulawun volcano, also known as the North Son, rises above the north coast of the island of New Britain across a low saddle NE of Bamus volcano, the South Son. The upper 1,000 m of the 2,334-m-high Ulawun volcano is unvegetated. A prominent E-W-trending escarpment on the south may be the result of large-scale slumping. Satellitic cones occupy the NW and eastern flanks. A steep-walled valley cuts the NW side of Ulawun volcano, and a flank lava-flow complex lies to the south of this valley. Historical eruptions date back to the beginning of the 18th century. Twentieth-century eruptions were mildly explosive until 1967, but after 1970 several larger eruptions produced lava flows and basaltic pyroclastic flows, greatly modifying the summit crater.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Langila

Papua New Guinea
5.525°S, 148.42°E; summit elev. 1,330 m

Activity detected by MODVOLC at Langila was minimal, with only one alert pixel for 2003 (9 April) recorded just above the detection threshold, even though activity observed during January and February 2003 included weak lava projections (*Bulletin* v. 28, no. 3). Four alert pixels were recorded for 2004, on 20 (one each on Aqua and Terra), 25, and 27 January. All were 1-pixel alerts, with the highest alert ratio on 27 January at -0.764.

A thorough search of MODIS image data (i.e. original data, rather than the thresholded alert data on the MODVOLC website) was made for the period 20 May-25 October 2002, which revealed single-pixel sub-threshold thermal anomalies on Langila on a total of 25 dates, strengthening the case for the quasi-continuous or intermittent activity interpreted on the basis of MODVOLC alerts (*Bulletin* v. 28, no. 1).

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. Langila, one of the most active volcanoes of New Britain, consists of a group of four small overlapping composite basaltic-andesitic cones on the lower eastern flank of the extinct Talawe volcano. Talawe is the highest volcano in the Cape Gloucester area of NW New Britain. A rectangular, 2.5-km-long crater is breached widely to the SE; Langila volcano was constructed NE of the breached crater of Talawe. An extensive lava field reaches the coast on the north and NE sides of Langila. Frequent mild-to-moderate explosive eruptions, sometimes accompanied by lava flows, have been recorded since the 19th century from three active craters at the summit of Langila. The youngest and smallest crater (the number 3 crater) was formed in 1960 and has a diameter of 150 m.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Dukono

Halmahera, Indonesia
1.68°N, 127.88°E; summit elev. 1,185 m

Based on MODVOLC thermal alert data, Coppola and Rothery had previously reported a significant thermal event during 26 August-7 September 2002 (*Bulletin* v. 28 no. 3). This was the first sign of activity at Dukono since the inception of MODVOLC data in May 2000. Subsequent reports from the Volcanological Survey of Indonesia and the Darwin VAAC (*Bulletin* v. 28, nos. 6, 9, and 11) documented ash eruptions in February and June-December 2003.

An updated analysis of MODVOLC data covering the period August 2000-April 2004 confirmed the August-September 2002 event by the addition of thermal alerts from NASA's Aqua satellite (26 August, 6 and 7 September 2002), but found very little sign of activity subsequently throughl the end of April 2004. During the whole period since September 2002 the only thermal alerts were single-pixel events, only slightly above the MODVOLC detection threshold, on 1 March and 10 November 2003. Inspection of raw MODIS data revealed an additional anomaly on 17 November 2003 with an alert ratio slightly below the MODVOLC detection threshold. The scarcity of thermal alerts at Dukono despite recurrent ash eruptions indicated the general invisibility (or small size) of any hot feature at the source, such as an incandescent vent or lava dome.

Data acquisition and analysis. Reports from Diego Coppola and David A. Rothery provided analyses of MODIS thermal alerts during 2001 and 2002 (using the MODVOLC alert-detection algorithm) extracted from the MODIS Thermal Alerts website (http://modis.hgip.hawaii.edu/) maintained by the University of Hawaii HIGP MODIS Thermal Alerts team (*Bulletin* v. 28, no. 1). Rothery and Charlotte Saunders provided updates to 31 May 2004. MODVOLC data are now routinely available from the Aqua satellite (equator crossing times 0230 and 1430 local time) in addition to the original Terra satellite (equator crossing times 1030 and 2230 local time).

Background. Reports from this remote volcano in northernmost Halmahera are rare, but Dukono has been one of Indonesia's most active volcanoes. More-or-less continuous explosive eruptions, sometimes accompanied by lava flows, occurred from 1933 until at least the mid-1990s, when routine observations were curtailed. During a major eruption in 1550, a lava flow filled in the strait between Halmahera and the north-flank cone of Gunung Mamuya. Dukono is a complex volcano presenting a broad, low profile with multiple summit peaks and overlapping craters. Malupang Wariang, 1 km SW of Dukono's summit crater complex, contains a 700 x 570 m crater that has also been active during historical time.

Information Contacts: *David A. Rothery* and *Charlotte Saunders*, The Open University (see Yasur).

Semeru

Java, Indonesia
8.108°S, 112.92°E; summit elev. 3,676 m
All times are local (= UTC + 7 hours)

According to the Volcanological Survey of Indonesia (VSI), Semeru remained at Alert Level II (on a scale of 1-4) for the entire report period of April-June 2004. VSI characterizes Level II as "increasing seismic activity and other volcanic events and visual changes around the crater" but also states that this definition implies "no eruption is imminent." A pilot reported an 18 June ash plume rising to 6 km.

During the week of 12-18 April, tectonic earthquakes and tremor increased. Plumes sometimes containing ash were observed reaching heights of 110-400 m above the summit. Other seismic signals (including those from explosions, avalanches, and tremor) also continued. The Darwin VAAC reported that an ash plume was visible in satellite imagery on 18 April, reaching a height of ~ 4.5 km and extending ~ 90 km NW.

During 19-25 April, white-gray ash plumes were observed reaching heights of 100-400 m above the summit. The Darwin VAAC reported that an ash plume was visible in satellite imagery on 20 April, reaching a height of ~ 4.5 km and extending ~ 75 km SSE. Another plume on 21 April rose to ~ 4.6 km altitude and drifted ESE. Increases occurred in tremor as well as tectonic earthquakes, shallow-volcanic earthquakes, and explosion earthquakes. The number of avalanche signals decreased (table 1).

During the week of 26 April-2 May, explosion and avalanche signals increased, with continuing tremor, and volcanic earthquakes. Tremor and explosion signals increased, but avalanche signals decreased, during the week of 3-9 May. White-gray ash plumes were observed reaching

Dates (2004)	Volcanic-A earthquakes	Volcanic-B earthquakes	Tremor	Tectonic earthquakes	Explosion signals	Avalanche signals
12 Apr-18 Apr	0	0	25	5	508	10
19 Apr-25 Apr	0	3	38	11	638	8
26 Apr-02 May	1	2	19	7	736	12
03 May-09 May	1	0	22	7	853	9
07 Jun-13 Jun	2	9	34	15	902	22
14 Jun-20 Jun	1	0	19	14	630	11
21 Jun-27 Jun	4	5	39	8	860	14
28 Jun-04 Jul	0	1	27	16	805	12

Table 1. Summary of seismicity at Semeru during 12 April-4 July 2004. The highest values in several categories occured during 7-13 June. Courtesy of VSI.

heights of 300-400 m above the summit during both weeks. The Darwin VAAC reported that a thin ash plume from Semeru was visible on satellite imagery on 23 May around 0625; it reached a height of ~ 4.3 km altitude and extended ~ 110 km SSE.

An ash plume from Semeru was reported on 4 June rising to ~ 4.5 km altitude During the week of 7-13 June, a white-gray plume was observed on a clear day rising to heights of 300-400 m above the summit. Seismographs recorded an increasing number of volcanic, tectonic, and tremor earthquakes, and explosion and avalanche signals compared to the previous week. Indeed, that week was the most seismically active on the basis of most parameters, with more than 900 explosion signals and more volcanic earthquakes, tremor, and avalanche signals than any other week (table 1).

Visual observation was difficult during 14-20 June due to fog, although a white-gray plume was observed on 18 June, rising to heights of 500-600 m above the summit. Based on a pilot's report, the Darwin VAAC reported that on 18 June an ash cloud from Semeru was visible at a height of ~ 6 km altitude, extending ~ 40 km E; this was the highest recorded ash cloud during the report interval. No ash was visible on satellite imagery. The number of volcanic, tremor, and tectonic earthquakes, and explosion and avalanche signals decreased from the previous week.

Foggy weather made visual observation difficult again during the week of 21-27 June. On one clear day a white-gray ash explosion was observed rising 500-600 m above the summit. Seismographs recorded volcanic, tremor, and tectonic earthquakes, and explosion and avalanche signals. Seismicity had generally increased, except for tectonic earthquakes, compared to the previous week.

During the week of 28 June-4 July, visual observations of the summit were again difficult because of cloud cover, but a gray ash plume was observed rising to 500-600 m above the summit on one clear day. Seismographs still recorded volcanic, tremor, and tectonic earthquakes, and explosion and avalanche signals.

Background. Semeru, the highest volcano on Java, and one of its most active, lies at the southern end of a volcanic massif extending north to the Tengger caldera. The steep-sided volcano, also referred to as Mahameru (Great Mountain), rises abruptly to 3,676 m above coastal plains to the S. Gunung Semeru was constructed S of the overlapping Ajek-ajek and Jambangan calderas. A line of lake-filled maars was constructed along a N-S trend cutting through the summit, and cinder cones and lava domes occupy the E and NE flanks. Summit topography is complicated by the shifting of craters from NW to SE. Frequent 19th and 20th century eruptions were dominated by small-to-moderate explosions from the summit crater, with occasional lava flows and larger explosive eruptions accompanied by pyroclastic flows that have reached the lower flanks of the volcano. Semeru has been in almost continuous eruption since 1967.

Information Contacts: *Dali Ahmad*, *Hetty Triastuty*, *Nia Haerani*, and *Suswati,* Vulcanological Survey of Indonesia (VSI), Jalan Diponegoro No. 57, Bandung 40122, Indonesia (Email: dali@vsi.dpe.go.id; URL: http://www.vsi.dpe.go.id/); *Darwin Volcanic Ash Advisory Centre (VAAC)*, Bureau of Meteorology, Northern Territory Regional Office, PO Box 40050, Casuarina, NT 0811, Australia (URL: http://www.bom. gov.au/info/vaac/).

Nyiragongo

DR Congo, Central Africa
1.52°S, 29.25°E; summit elev. 3,470 m

When last reported on, activity at Nyiragongo remained at relatively low levels, with the continued presence of an active lava lake inside the crater (*Bulletin* v. 28, no. 12). Continued activity in May and June 2004 was characterized by weak emissions that produced ash plumes to various heights.

Activity during May 2004. The Toulouse VAAC reported that satellite imagery showed a weak eruption of Nyiragongo on 21 May. Activity intensified during the evening of 24 May, with thermal anomolies and aerosol plumes visible in true- and false-color satellite imagery on 25 May (figure 13). By the evening of 25 May, the plume was no longer visible on satellite imagery due to meteorological clouds in the area. The Toulouse VAAC reported that during 26 May to 1 June there were weak but steady emissions from both Nyiragongo and neighboring Nyamuragira (~ 13 km NW of Nyiragongo). The Goma Volcano Observatory confirmed that ash fell within a radius of 60 km of both volcanoes.

Activity during June 2004. A series of plumes were noted, several to estimated altitudes of over 5 km. On 4 June a new eruption began at Nyiragongo, producing a plume that probably contained ash. It rose to ~ 6 km altitude and stretched ~ 150 km SW. By 5 June the plume extended 185 km SW and was under ~ 4 km altitude. On 6 June, satellite imagery showed only a moderate plume stretching to the SW and a disconnected remnant of the earlier plume. The moderate plume, drifting SW, remained through 7 June. An ash plume extended ~ 75 km SW at ~ 5.5 km altitude on 8 June. During 9-15 June, ash from Nyiragongo was sometimes visible on satellite imagery below ~ 5.5 km altitude drifting WSW. Satellite imagery suggested that the ash emissions that began on 4 June ceased by 22 June.

Background. One of Africa's most notable volcanoes, Nyiragongo contained a lava lake in its deep summit crater that was active for half a century before draining catastrophically through its outer flanks in 1977. In contrast to the low profile of its neighboring shield volcano, Nyamuragira, Nyiragongo displays the steep slopes of a stratovolcano. Former lava lakes, which have been observed since the late-19th century, are marked by benches in the steep-walled 1.2-km-wide summit crater. Two older stratovolcanoes, Baruta and Shaheru, are partially overlapped by Nyiragongo on the north and south. About 100 parasitic cones are located primarily along radial fissures south of Shaheru, east of the summit, and along a NE-SW zone extending as far as Lake Kivu. Many cones are buried by voluminous lava flows that extend long distances down the flanks of the volcano, which is characterized by the eruption of foiditic rocks. The extremely fluid 1977 lava flows caused many fatalities, as did lava flows that inundated portions of the major city of Goma in January 2002.

Information Contacts: *Tolouse Volcanic Ash Advisory Center (VAAC)*, Toulouse, Météo-France, 42 Avenue G. Coriolis, 31057 Toulouse Cedex, France (Email: vaac@meteo.fr; URL: http://www.meteo.fr/aeroweb/info/vaac/homepage/eindex.html); *Goma Volcano Observatory*, Departement de Geophysique, Centre de Recherche en Sci-

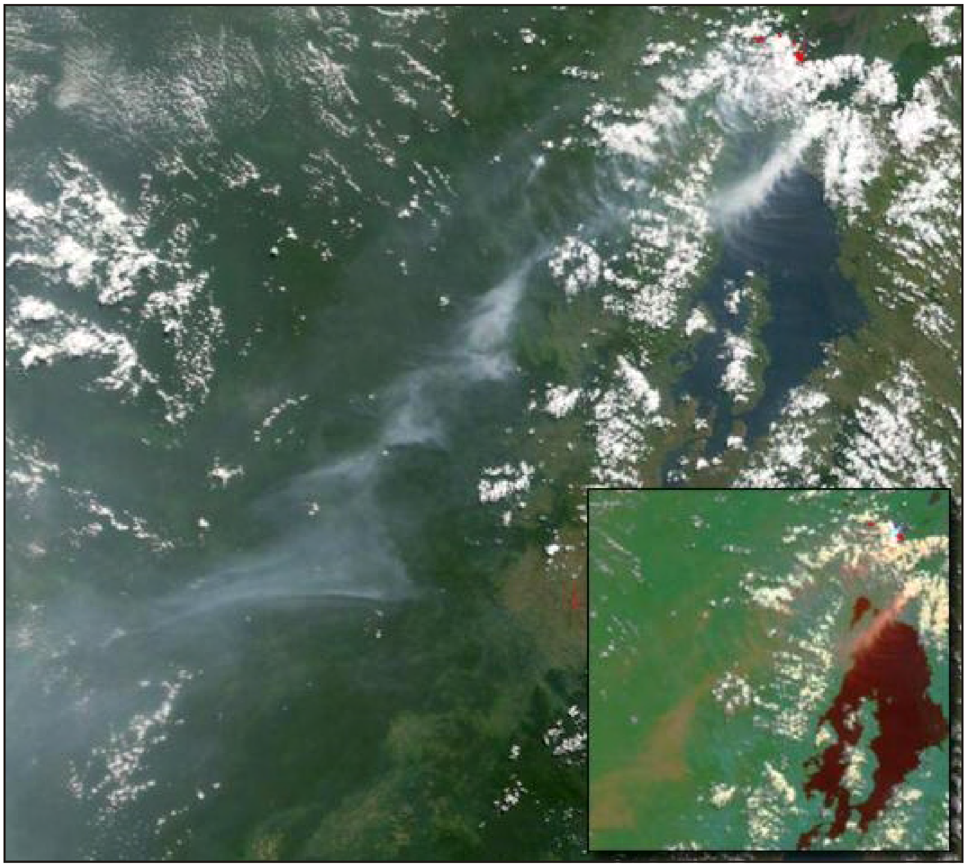

Figure 13. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite captured these images of the Nyriagongo eruptions of 25 May 2004. The volcano lies above (~ 20 km N of) the water body (Lake Kivu) on the right. The large image shows the scene in true color at MODIS' maximum resolution of 250 m per pixel. Red dots around Nyiragongo indicate pixels with thermal anomalies and may result from flowing lava or fires. The inset shows the area around the volcanoes in false color adjusted to enhance the difference between meteoric clouds and the aerosol plumes. The latter are a darker color and may contain ash and steam or smoke from fires. Courtesy of Jesse Allen, based on data from the MODIS Rapid Response Team at GSFC.

ences Naturelles, Lwiro, D.S. Bukavu, DR Congo (Email: ocha.volcan@wfp.org).

Guagua Pichincha

north-central Ecuador
0.171°S, 78.598°W; summit elev. 4,784 m
All times are local (= UTC - 5 hours)

This report is a summary of notable activity at Guagua Pichincha since September 2001 (*Bulletin* v. 26, no. 9). On 26 November 2001, seismic data indicated that an ~ 20-minute-long phreatic explosion began around noon and that continuous tremor was recorded for ~ 16 hours after the eruption. This was the first explosion since 25 May 2001 (*Bulletin* v. 26, no. 9). Seismic signals from a relatively high number of rockfalls were also recorded. Two new craters were formed N of the 1981 crater by the 26 November 2001 event. Volcanic and seismic activity returned to low levels after 27 November, with only low-level fumarolic activity occurring.

The next event of note occurred on 11 October 2002 following 6 months with no explosions, as reported by the *El Universo* newspaper. Four phreatic eruptions were presumably triggered by groundwater encountering the magmatic system after several days of heavy rainfall. The eruption sent ballistic blocks to distances of 100-200 m from the vent. Subsequently, long-period and volcano-tectonic earthquakes and continuous background tremor were recorded until 17 October.

The Washington VAAC reported explosions at 2056 and 2115 on 3 November 2002 and at 2120 on 7 December. The Washington VAAC was unable to determine the heights of the plumes produced from the explosions in November, or state if they contained ash, because ash was already in the atmosphere from a large eruption that day at Reventador, ~ 100 km E of Guagua Pichincha.

On 17 April 2003, the Instituto Geofísico (IG) detected seismic signals indicating a possible minor eruption, but there were no visual signs of ash venting. Similar seismic signals in the previous few days were thought to result from outgassing. Several volcano-tectonic earthquakes, one long-period earthquake, and seismic signals of rockfalls were also reported. During the week of 23-29 April 2003, seismic unrest continued. Typically several earthquakes were detected per day, but 16 long-period earthquakes occurred on 26 April. Subsequently, the volcano exhibited low-to-moderate seismicity, including two earthquakes with M < 3 on 30 April and 1 May. Both had epicenters within an earthquake swarm centered N of Quito. Episodes of harmonic tremor appeared, most noteworthy on 4 and 5 May, with each episode lasting over 40 minutes. Cloud cover obscured the crater area for much of the week but improved visibility on 3 May enabled observers to see fumaroles sending condensate up to heights of 100 m.

During the afternoon of 7 January 2004, strong rains occurred and seismic signals attributed to rockfalls and lahars were recorded. A visit to the area by IG scientists on 13 January confirmed that a lahar had traveled down the NNE wall of the volcano's crater. In addition, there were small fractures in the SE sector of the volcano and in the crater but IG noted that this activity did not indicate a change in volcanic activity at Guagua Pichincha.

Background. Guagua Pichincha and the older Pleistocene Rucu Pichincha stratovolcanoes form a broad volcanic massif that rises immediately to the west of Ecuador's capital city, Quito. A lava dome is located at the head of a 6-km-wide breached caldera that formed during a late-Pleistocene slope failure of Guagua Pichincha about 50,000 years ago. Subsequent late-Pleistocene and Holocene eruptions from the central vent in the breached caldera consisted of explosive activity with pyroclastic flows accompanied by periodic growth and destruction of the central lava dome. Many minor eruptions have occurred since the beginning of the Spanish era at Guagua Pichincha, which is one of Ecuador's most active volcanoes. The largest historical eruption took place in 1660, when ash fell over a 1000 km radius, accumulating to 30 cm depth in Quito. Pyroclastic flows and surges also occurred, primarily to the west, and affected agricultural activity, causing great economic losses.

Information Contacts: *Instituto Geofísico (IG)*, Escuela Politécnica Nacional, Apartado 17-01-2759, Quito, Ecuador (URL: http://www.epn.edu.ec/~ igeo/); *Washington Volcanic Ash Advisory Center (VAAC)*, Satellite Analysis Branch, NOAA/NESDIS E/SP23, NOAA Science Center Room 401, 5200 Auth Road, Camp Springs, MD 20746 USA (URL: http://www.ssd.noaa.gov/).

Santa María

Guatemala
14.756°N, 91.552°W; summit elev. 3,772 m

Recent activity at Santa María has been characterized by weak-to-moderate explosions producing ash, crater-rim collapses and avalanches of block lava and ash, pyroclastic flows, and an active lava flow (*Bulletin* v. 28, no. 10). Activity was similar from October 2003 to June 2004, consisting mostly of explosions from Santiaguito, a lava-dome complex that includes the Caliente vent. The explosions produced ash plumes, and there were numerous block-lava-and-ash avalanches from Caliente collapses.

Activity during October-November 2003. Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH) reported frequent explosions during October 2003 (*Bulletin* v. 28, no. 10). The Washingon VAAC noted low-level ash plumes visible in 31 October satellite imagery.

As of 17 November, according to INSIVUMEH, several weak-to-moderate eruptions from the lava dome complex sent plumes to ~ 700 m above the crater that drifted SW. According to the Washington VAAC, a pilot saw a plume above Santa María on 16 November; the narrow plume was visible on satellite imagery extending ~ 35 km W. Small eruptions on 18 and 23 November produced local tephra fall. Small avalanches occurred on 18 November. On 24 November five explosions occurred at 1-minute intervals, producing an ash-and-gas plume that rose to 2 km above the crater and dispersed up to 12 km SSW.

On 28 November the seismic network recorded several explosions. INSIVUMEH noted that many of the explosions were followed by block-and-ash avalanches, which traveled SW and S down the Caliente dome. At least five collapses of megablocks from the S rim of the active vent generated short pyroclastic flows to the base of the Caliente dome. On 1 December ash emissions drifted SE and nearly constant avalanches occcurred in the active lava-flow area.

Activity during December 2003. During 7-9 December, frequent, small explosive eruptions expelled ash to less than 1 km above the crater that dispersed to the NW. Moderate-sized avalanches from the S and SE sides of the dome were recorded during the same time period. Weak-to-moderate explosions continued during 10-16 December. On 10 December ash mainly drifted SE toward Santa María de Jesús and las Majadas. Avalanches traveled S and SW from the fronts of lava flows. According to the Washington VAAC, on 12 December ash clouds were visible on satellite imagery at an altitude of ~ 4.5 km, drifting SW.

During 18-22 December, weak-to-moderate explosions caused plumes to drift mainly S and SE towards the Monte Claro, Monte Bello, La Florida, and El Faro fincas (ranches). Nearly constant avalanches traveled S and SW from the fronts of lava flows. Based on information from Retalhuleu airport, the Washington VAAC reported a minor emission on 18 December. No ash was visible on satellite imagery.

On 30 December more weak-to-moderate explosions sent ash-and-gas plumes 500-700 m high. They drifted SW and deposited fine ash in a mountainous region with several ranches. Avalanches continued to spall off of lava-flow fronts on the volcano's SW and S flanks and occasionally from the Caliente dome.

Activity during January 2004. According to seismic data, during 1-5 January weak-to-moderate explosions occurred, causing block-and-ash avalanches to travel 100-250 m down the volcano's SW and S flanks and the Caliente dome. Small amounts of ash fell around the volcano.

During 7-12 January, several weak-to-moderate explosions and avalanches occurred. A partial lava-dome collapse on 7 January produced avalanches down the SW flank. Many of the avalanches were moderate to strong, lasting 1-2 minutes as they traveled SW and S down Caliente dome. Explosions on 12 January produced plumes to ~ 500 m above the volcano. Ash plumes were also visible on satellite imagery several days during the report period.

On the morning of 15 January a moderate explosion at the dome caused a collapse at the edge of the crater. Volcanic material traveled down the SW flank, reaching the base. Ash rose ~ 900 m above the crater and fell on the observatory. Weak avalanches occurred in the SE portion of the lava dome. On 19 January moderate explosions occurred and avalanches descended the lava dome. The plumes produced from the explosions traveled E, depositing small amounts of fine ash around the volcano, including on the ranches of San Jose, Quina, and San Juan Patzulín.

During 21-27 January, weak-to-moderate explosions continued. Avalanches of blocks of lava and ash descended the S and SW flanks of the Caliente dome and explosions produced low-level ash plumes. Small-to-moderate explosions continued during 28 January to 2 February. During 31 January to 2 February, collapses occurred at the SW edge of the lava dome within the Caliente dome. Ash plumes rose to ~ 1 km above the lava dome, accompanied by small avalanches of blocks and ash. According to the Washington VAAC, on 2 February ash plumes were visible on satellite imagery rising to ~ 1 km above the volcano.

Activity during February 2004. During 4-9 February, small-to-moderate explosions occurred, and relatively weak avalanches traveled down Santa María's SW flank. According to the Washington VAAC, ash plumes were visible on satellite imagery on 5 February ~ 2.3 km above the volcano. INSIVUMEH reported that on the morning of 8 February, an explosion produced an ash-and-gas cloud that rose 1-1.3 km above the volcano and drifted WSW.

During 11-16 February, small-to-moderate explosions produced ash plumes to a maximum height of 1.4 km above Santa María. In addition, avalanches went down the volcano's SW flank. Explosions on 16 February deposited fine ash up to 12 km SW. Moderate explosions continued on 19

February. Plumes rose 0.7-1 km above the volcano and mainly drifted SSW as fine ash fell in the mountainous region around the volcano. On 23 February, avalanches of lava blocks and derived ash moved SW down the dome.

During 25 February to 2 March, weak-to-moderate explosions continued. Ash-and-gas plumes rose to ~ 1.4 km above the crater, and ash fell in the mountainous region around the volcano. Weak-to-moderate avalanches of volcanic material was shed from lava-flow fronts.

Activity during March 2004. During 4-9 March, small-to-medium explosions occurred, producing ash-and-gas plumes to 1.5 km above the crater. Avalanches traveled S and SW. Small-to-medium explosions continued during 10-15 March, producing ash-and-gas plumes to ~ 1. 3 km above the crater. A small partial collapse on 10 March sent pyroclastic flows down the SSW flank. During the rest of the period, weak avalanches traveled S and SW.

During 15-23 March, several small-to-medium explosions produced ash-and-gas plumes to ~ 1.5 km above the crater. Incandescent avalanches traveled SW from the lava dome. In addition, ash fell in proximal areas. A partial lava-dome collapse on 17 March sent a pyroclastic flow down the volcano's flanks. Weak to moderate explosions produced plumes up to 1 km high during the week of 24-30 March. Light ashfall occurred in nearby areas on several occasions. On 25 March incandescent avalanches from the S flank of the Caliente dome flowed to the SE. Lahars descended the Nimá I river on 28 March and the Nimá I and Nimá II rivers on the evening of 29 March.

Activity during April 2004. During 31 March to 6 April, weak-to-moderate explosions continued, producing plumes to 1.3 km above the volcano. Several partial lava-dome collapses produced avalanches down the S flank. A strong explosion on 1 April caused a collapse and produced a pyroclastic flow that moved ~ 4 km SW toward the Nimá II river. On 12 April weak-to-moderate explosions sent plumes 500-800 m above the volcano. Avalanches of lava blocks and ash traveled down the S flank.

On 18 April, explosions at the lava dome produced ash-and-gas plumes that rose up to ~ 0.8 km above the vent. Small avalanches of incandescent lava also descended the SW side of the Caliente dome. On 19 April, an ash-and-gas plume rose to ~ 4.5 km altitude and drifted SW.

During 22 April-4 May, explosions produced ash-and-gas plumes that rose to ~ 1 km above the crater. Small incandescent avalanches descended the SW side of the Caliente dome. An explosion on 27 April produced a pyroclastic flow that traveled ~ 3 km to the SW.

Activity during May 2004. During 5-7 May, weak-to-moderate explosions sent ash-and-gas plumes to ~ 900 m above the crater. Small partial collapses at the edge of the Caliente dome produced incandescent avalanches to the SW. Weak-to-moderate explosions continued during 10-17 May, producing ash-and-gas plumes that rose to ~ 1 km above the crater. Small partial collapses at the edge of the Caliente dome produced incandescent avalanches to the SW. On 17 May a lahar traveled S down Nimá River I.

During 18-21 May, weak-to-moderate explosions produced ash-and-gas plumes that rose to ~ 1 km above the crater. Many of the moderate explosions were accompanied by incandescent avalanches. On 20 May aa small partial collapse at the edge of the Caliente dome produced an incandescent avalanche to the SW base of the dome. Weak-to-moderate explosions during 31 May-1 June produced ash-and-gas plumes that rose ~ 1.5 km above the crater. Small collapses at the edge of the dome sent avalanches of incandescent material down the SW flank.

Activity during June 2004. On 1 June, 33 weak to moderate explosions producing plumes up to 1.5 km above the summit were recorded. Collapses on the SW side of Caliente produced small pyroclastic flows that descended to the base of the Caliente and La Mitad domes. During 6-8 June, many weak to moderate explosions sent ash-and-gas plumes up to ~ 1.5 km above the Caliente dome, along with some avalanches and flank collapses. Moderate-volume lahars descended the Nimá Segundo river and San Isidro ravine on 1 and 6 June, respectively.

INSIVUMEH reported that on 18 June weak-to-moderate explosions sent ash plumes to 0.4-1 km above the crater. The plumes drifted W, depositing fine ash. According to the Washington VAAC, satellite imagery showed three ash emissions on the 18th that rapidly moved W, becoming more diffuse near the Mexican border. Weak-to-moderate explosions occurred during 25-29 June. Plumes rose to ~ 1 km above the crater and there were sporadic, weak avalanches. On 28 June a partial collapse sent material down the W side of Caliente dome for ~ 40 minutes.

Background. Symmetrical, forest-covered Santa María volcano is one of a chain of large stratovolcanoes that rises dramatically above the Pacific coastal plain of Guatemala. The stratovolcano has a sharp-topped, conical profile that is cut on the SW flank by a large, 1-km-wide crater, which formed during a catastrophic eruption in 1902 and extends from just below the summit to the lower flank. The renowned plinian eruption of 1902 followed a long repose period and devastated much of SW Guatemala. The large dacitic Santiaguito lava-dome complex has been growing at the base of the 1902 crater since 1922. Compound dome growth at Santiaguito has occurred episodically from four westward-younging vents, accompanied by almost continuous minor explosions and periodic lava extrusion, larger explosions, pyroclastic flows, and lahars.

Information Contacts: *Instituto Nacional de Sismologia, Vulcanologia, Meteorologia e Hidrologia (INSIVUMEH)*, Unit of Volcanology, Geologic Department of Investigation and Services, 7a Av. 14-57, Zona 13, Guatemala City, Guatemala (URL: http://www.insivumeh.gob.gt/); *Washington VAAC* (see Guagua Pichincha).

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