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Cover photos: left, Shishaldin steaming on 5/26/99, photo taken by Jim Beget; right, Shishaldin in eruption, April, 1999, photo by G. McGimsey.

In This Issue

Highlights and Summary

- Shishaldin erupts!
- Bezymianny erupts in Kamchatka
- An earthquake of M 5.0 occurs beneath the west flank of Shishaldin
- Updated background seismicity rates are reported for all monitored volcanoes
- Volcanic processes are being investigated by AVO personnel using a new Experimental Petrology Laboratory

There has been a dearth of effusive excitement since the intra-caldera lava flow at Okmok Volcano in the spring of 1997. This situation was corrected, however, with a major explosive eruption of Shishaldin Volcano on April 19, sending ash to 45,000 feet. As has become common in the history of AVO, the eruption followed the completion of the local seismic net by less than a year. However, no one at AVO has stepped forward to propose a cause-and-effect relationship: the triggering of eruptions by installation of seismic instruments. A more plausible trigger, or at least associated phenomenon caused by the rise of new magma beneath the cone, was an M 5.0 earthquake beneath the west flank of the volcano. This event was followed by hundreds of aftershocks. Since signs of unrest in the form of anomalous steaming, satellite-detected thermal anomaly, and weak seismic tremor – in that order of occurrence – preceded both the earthquake and the eruption, it would appear that the earthquake was not the ultimate cause. One can be more certain about the effectiveness of AVO's tripartite approach to monitoring an active volcano that is more than 1000 km away from home. Synthesis of eye-witness (ground and pilot) reports, satellite thermal infrared (AVHRR), and six real-time telemetered seismic stations ringing the cone provided us with a rather complete understanding of what the volcano was doing. This information was of major importance to the aviation community, as ash did reach flight levels. If there is a lesson here, it is how surprisingly long a lead time can be provided by precursory signals for even a basaltic event, if an adequate level of vigilance is maintained. It remained for the next report period to visit and sample the deposits of the eruption on the ground. This adventure will be described in our next exciting issue.

John Eichelberger
Coordinating Scientist
Alaska Volcano Observatory

Eruptions

Shishaldin eruption winter-spring 1999

Unrest at Shishaldin Volcano was identified in early February by onset of weak tremor combined with the appearance of a small thermal anomaly at the summit. At the same time, several M4+ earthquakes with many aftershocks were located off the flank west of the volcano. The earthquakes were presumably related to an older structure rather than to the intrusion itself, though very likely magma intrusion at Shishaldin had some effect on the tectonic earthquakes. AVO went to color code yellow and 24-hr duty on 18 February 1999. Both the tremor seismicity and the thermal anomaly persisted and gradually increased over the next few months. On 17 April, AVO personnel accompanying the Alaska State Troopers on a flight equipped with a Forward Looking InfraRed (FLIR) video instrument recorded low-level strombolian activity in the summit crater of Shishaldin Volcano. On 19 April, an eruption sent an ash column to 45,000 ft asl with heavy fallout on the south flank of the volcano and an ash plume that drifted south. The exact time of the eruption was detected by a sharp increase in the real-time reduced displacement plots for the seismic tremor and the eruption column was observed on satellite imagery. Fortuitously, AVO staff on a Reeve Aleutian flight to Adak witnessed the eruption column as the aircraft approached Cold Bay for a landing. A second major explosion on 22 April sent ash to about 20,000 ft asl. Lesser events with ash plumes as high as 15,000 ft asl and drifting as far as 110 miles downwind occurred several times during the next month and were detected by both seismicity and satellite imagery. Shishaldin was downgraded to color code green on 18 June.

This eruption was an excellent example of the combined use of satellite imagery and seismicity to follow unrest and eruption of a frequently active, rather mafic volcano that exhibited only tremor seismicity (with a few LPs between the two major events). Using the spectrograms and reduced displacement plots, especially with the strong Aleutian wind noise plotted as well, proved a unique and useful tool. Careful analysis of the satellite imagery indicated the magma rising in the vent as tremor seismicity gradually built up. The opportune FLIR flight added significantly to our knowledge and, of course, AVO staff on site for visual observations gave verification to interpretations.

The next bimonthly report should provide some interesting details regarding this eruption. Following is a log of activity and Level of Concern Color Code for the Shishaldin volcanic eruption:

1/9/99 report from NWS Cold Bay of anomalous steam plume 10,000-15,000 ft asl above Shishaldin and extending several tens of km to the NE Late January slight tremor seismicity identified as more consistent pattern than the usual storm wind noise.

2/9/99 thermal anomaly first detected and NWS Cold Bay report of steam plume to 6,000 ft above the vent.

2/12/99 anomalous steam activity first reported in AVO Weekly Update.

2/18/99 Color Code Yellow on basis of low-level tremor, persistence of thermal anomaly, and steam plume to 19,000 ft asl.

3/4/99 M5.0 regional eq near Shishaldin followed by hundreds of aftershocks.

4/7/99 Color Code increased from Yellow to Orange on basis of increase in tremor.

4/12/99 Color Code reduced from Orange to Yellow as seismic tremor and thermal anomaly held steady and no indication of escalated activity.

4/14/99 Color Code increased from Yellow to Orange as seismicity increased markedly.

4/17/99 FLIR observations showed first confirmation of strombolian eruption in the summit crater.

4/19/99 Color Code increased from Orange to Red as sharp increase in seismic tremor indicated major event at 11:33am ADT. Ash plume went as high as 45,000 ft asl and pulsing activity was sustained for about 7 hrs.

4/20/99 Color Code downgraded from Red to Orange as seismicity decreased, but the thermal anomaly persisted.

4/21/99 Color Code increased from Orange to Red as tremor increased.

4/22/99 Color Code decreased from Red to Orange as moderate strombolian activity continued and satellite imagery continued to show a large thermal anomaly.

4/22/99 Color Code increased from Orange to Red as tremor increased and second major event occurred at 9:00pm ADT putting an ash plume to about 20,000 ft asl and continuing for about 5 hours.

4/23/99 Color Code changed from Red to Orange with decrease in tremor but thermal anomaly persists.

4/28/99 Color Code decreased from Orange to Yellow with further decrease in seismic tremor and thermal anomaly is not detectable.

5/13/99 small steam and ash burst reported.

5/25/99 Color Code increased from Yellow to Orange as ash-rich plume at about 15,000 ft asl and extending 110 miles south is detected on satellite imagery.

5/27/99 ash has diminished but thermal anomaly in visible in satellite imagery.

5/28/99 AVO staff visits Shishaldin for ground observations, mapping, and sampling.

6/1/99 Color Code reduced from Orange to Yellow on basis of low seismicity and no detectable thermal anomaly.

6/18/99 Color Code reduced from Yellow to Green as there is no further activity and seismicity returned to background levels.

Terry Keith and Game McGimsey

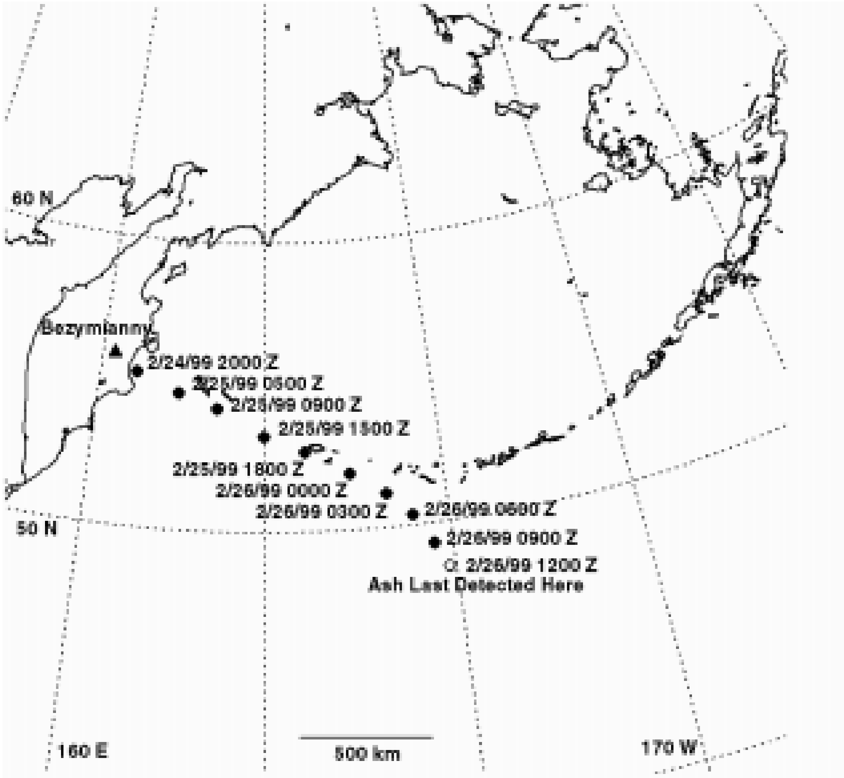

Figure 1: Movement of the volcanic ash cloud from Bezymianny Volcano, Russia, as detected in GOES satellite images. All times shown as Zulu (Z) time; KST=Z+12.

Eruption of Bezymianny Volcano, Russia: February 25, 1999

Bezymianny Volcano is a 2895 m high stratovolcano located in central Kamchatka Peninsula, Russia (55.9 N, 160.6 E). Bezymianny has had more than 30 explosive eruptions since 1957, making it one of the most active volcanoes in Kamchatka. During this most recent event, increased thermal activity was observed by AVO remote sensing scientists in AVHRR satellite images beginning on February 13, 1999. This information was immediately communicated to scientists from the Kamchatka Volcanic Eruptions Response Team (KVERT). A concurrent increase in seismic activity was also observed by KVERT, and the level of concern color code was upgraded by KVERT from green to yellow on February 15. Based on past behavior, these observations were interpreted as being related to renewed dome growth, and intermittent small-scale collapses and associated hot rock avalanches. Over the next 12 days, the intensity of the thermal anomaly grew in size and intensity.

An explosive phase of the Bezymianny eruption began on February 25 with two large explosions at 6:46 AM and 7:20 AM KST (2/24/99 at 18:46 and 19:20 Z). Ground observations from 7:30 AM KST estimated the height of the cloud at 5,000 m above the volcano (about 25,000 feet above sea level), and the level of concern color code was increased to orange. The eruption was detected independently by AVO in an AVHRR satellite image from 8:30 AM KST (2/24/99 at 20:30 Z), and this information was immediately communicated to the National Weather Service and the Federal Aviation Administration. The volcanic ash cloud was tracked in GOES satellite data for 1500 km to the southeast using satellite imagery (fig. 1), as it entered Alaskan airspace. By 0030 AM KST on February 27 (1230 Z on February 26), the cloud had dissipated and was no longer detected, and KVERT decreased the level of concern color code to yellow. A thermal anomaly was observed at the volcano in satellite images for several days after the explosive eruption, but at a lower level of intensity. With seismicity at background levels, and the thermal anomaly no longer present, KVERT reduced the level of concern color code to green on March 9.

Dave Schneider

Monitoring

Satellite Observations of Alaska and Kamchatka Volcanoes

AVO monitors volcanoes in Alaska and Kamchatka using the relatively high spatial resolution and nadir view of Polar Orbiting satellite data, and the high temporal resolution of Geostationary satellite data. All of these systems include visible and thermal infrared wavelength data.

The Polar Orbiting system is the Advanced Very High Resolution Radiometer (AVHRR) on the NOAA-12 and -14 satellites. Images are recorded in five spectral bands at a spatial resolution of 1.1 km at nadir. Alaskan volcanoes are received by the ground station at the Geophysical Institute, University of Alaska Fairbanks, and are analyzed daily to detect volcanic eruption clouds and thermal anomalies at volcanoes in the North Pacific region. Repetitive coverage by these data are 8 images per 24 hours for Alaska volcanoes and approximately 4 images per 24 hours for Kamchatka volcanoes. The timing of satellite passes are not distributed evenly over the 24 hour time frame.

Geostationary data are received from the GMS and GOES satellites via computer networks at AVO-Anchorage, and provide off nadir observations of the western North Pacific (GMS), and the eastern North Pacific (GOES). Hourly GMS data (~8km resolution at 60°N in the visible and TIR) are available for analysis within ~1 hour after reception by a ground station. GOES data are available at 15 minute intervals at resolutions of ~2 km at 60°N (visible band), and at 30 minute intervals at 8 km at 60°N (Vis and TIR bands), respectively within 45 minutes after reception by a ground station.

This four month period has been exciting due to volcanic activity at Shishaldin, Karymsky, Bezymianny, Sheveluch, and Klyuchevskoy volcanoes. Satellite observations consisted of increased surface temperatures at volcanoes, and

continued

Table 1. Satellite Obsevations of Alaska and Kamchatka Volcanoes for the months of January-April, 1999

Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
January																															
Karymsky				X									X					X		XP		P			X						
Kluichevskoi									XP																						
February																															
Bezymianny															X	XP	XP	X				XP	X	XP	X	X	X				
Karymsky			X						X	X					XP	X	X	X						X							
Shishaldin									XP			X	X				XP		XP						X		X	X			
March																															
Bezymianny					X																										
Karymsky														X								P									
Shishaldin					X	X	X		X		X	X	X		X	X	X		X	X			X				X	X	X	X	X
April																															
Bezymianny																			XP												
Karymsky																												X			
Sheveluch												XP																			
Shishaldin		X	X	X			X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	XP	P					

x=hot spot
p=plume

Figure 2. The thermal anomaly and steam plume in image n15.99040.1928 overlain on a space shuttle photograph of Unimak Island (STS047-077-034). Each AVHRR pixel is ca. 1.1 km on a side. The bright spot at the summit represents a temperature of 11 degrees centigrade. The zenith angle for this image was 14 degrees.

airborne plumes. The eruption of Shishaldin Volcano on Unimak Island was the longest lasting event of this period, while activity at Karymsky, Bezymianny, Sheveluch and Kluichevskoi volcanoes occurred periodically (Table 1 above).

Shishaldin Volcano

On 9th February, an ash-poor plume (AVHRR image n12.99040.1822) and a thermal anomaly (image n15.99040.1919) were observed at Shishaldin Volcano by S. Worley (fig. 2). This was the beginning of a four-month satellite monitoring effort at a heightened-alert status. Over this period mostly hot spots and a few steam plumes were observed. The most energetic eruption occurred on Julian Day (JD) 109 (19 April) when the eruption column rose to 45,000 ft. over a 4 hour period seen on successive GOES 10 satellite images (fig. 3). Surprisingly, the ash-rich plume could not be tracked for very long using the split window technique (Subtraction of thermal bands to highlight volcanic ash). This suggests that the ash cloud dissipated rapidly, or the signal was obscured by clouds, or a particle size was too large to be detected by AVHRR band width.

Numerous thermal anomalies were frequently observed on the satellite data starting in mid February to the end of April (fig. 4). The thermal anomalies initially occupied one pixel (< 1km^2) per image up to JD 65 and then 2 or more hot pixels were regularly observed (fig. 5). The largest thermal anomaly was over 25 pixels on April 23rd (fig. 6). These estimated counts are minus the look angle effect. Beginning on JD 66, the maximum temperature values of the pixels saturated (above ca. 50 C) the AVHRR sensor. The narrow (300 m diameter), deep crater (depth unknown) made it

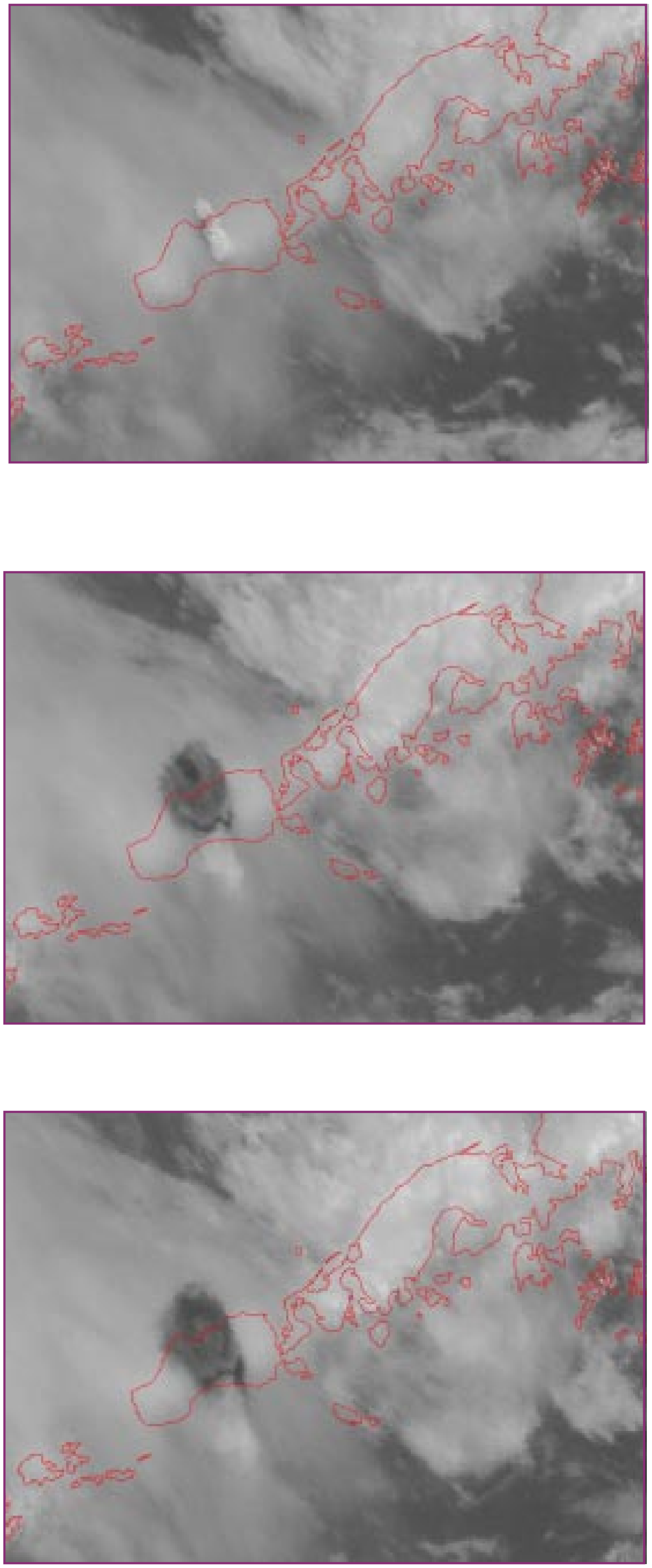

Figure 3; Consecutive images of the Shishaldin eruption plume from the GOES 10 on the 19th of April at 1945(a), 2015(b) and 2030(c) UTC. The plume breaches the cloud layer, rising to at least 45,000 ft. asl. A dark shadow is cast to the north as the plume drifts south and the coarse tephra quickly falls out.

difficult to observe the heat source from satellite. Initially, observations of the thermal anomaly were observed when the satellite zenith angle was < 25 degrees for the first 20 days (JD ~40 – 60), as noted by D. Schneider. After JD 60 the thermal anomaly became detectable on data with steadily increasing zenith angle. This implied that the heat source was rising in the central crater. The rate of rise calculated from these observations suggests that the thermal source would have reached the level of the summit around the 21st of March (JD 80). An airborne observation on April 17th, (Fig. 7) using the forward-looking infrared radiometer (FLIR) recorded strombolian activity at the vent. This activity is clearly responsible for at least some of the thermal anomalies seen on satellite imagery, and likely started sometime after JD 65.

The Shishaldin eruption produced several plumes during this observation period. Generally, these were narrow and ash-poor based on the only slightly negative values in the subtraction of AVHRR bands 4 minus 5, except for the eruptions on JD 109 (Fig. 3), JD 113 (Fig. 6) and JD 116. Other than the JD 109 event, the plumes were relatively short (less than 170 km in length), low-altitude (less than 20,000 ft.) based on their temperature, and their directions were variable, though generally to the south-south east.

Karymsky Volcano

Hot Spots were observed in early and mid January and plumes were emitted on 20th and 22nd January that were 90 to 130 km in length. Maximum temperatures were observed in image n14.99020.1632 at 40 degrees C with background temperatures approximately –30 degrees C. In February, thermal anomalies were observed on the 3rd from the 15th to18th with temperatures ranging from –3 to 19 degrees C. An ash poor plume was observed on 15 February that was about 50 km in length. In March, thermal anomalies were observed on the 14th and 22nd with temperature approximately 25 degrees above background. A plume was observed on March 22nd approximately 150 km to the east. In April, a weak anomaly was observed with a maximum temperature of 5 degrees C with background temperatures approximately –10 degrees C.

Bezymianny Volcano

Thermal anomalies and plumes were observed between 15 – 27 February with activity decreasing in March and April. On 5 March, temperatures were approximately 25 degrees above background temperature. In April a plume

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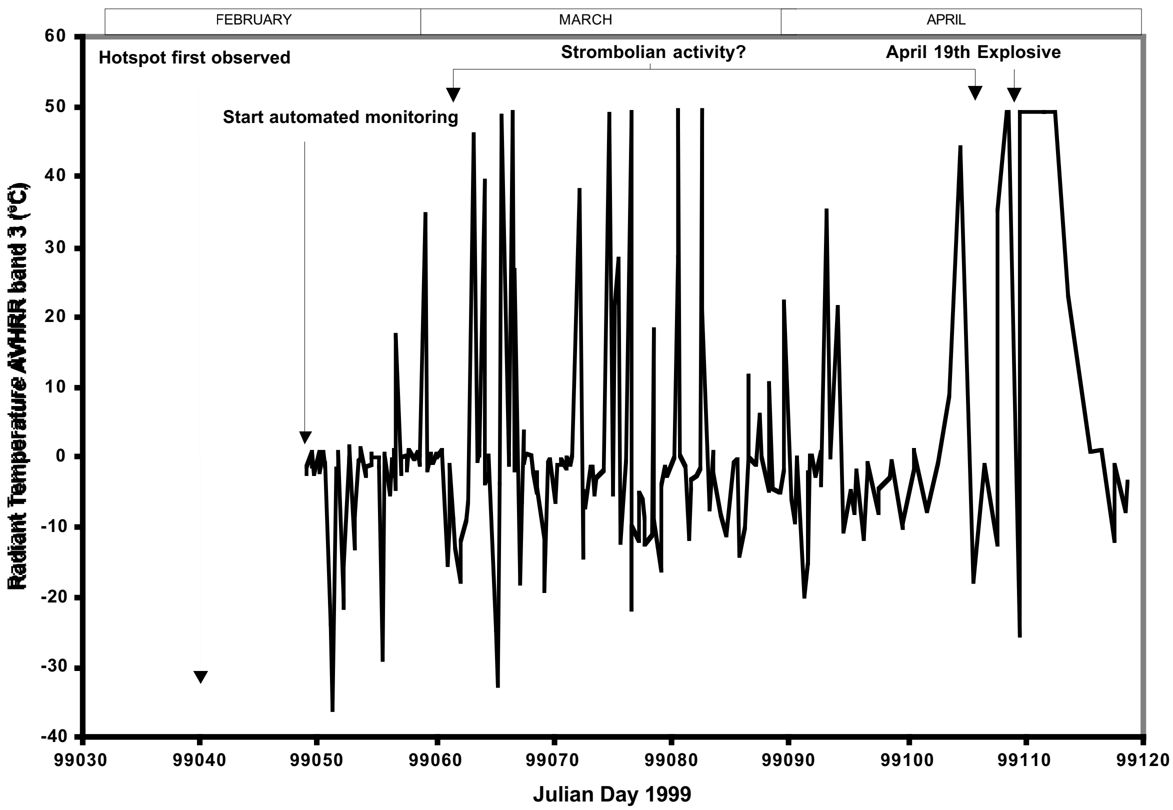

Figure 4: Temperature versus time graph of AVHRR band 3 data from night-time images of Shishaldin from early February through April. The data were recorded automatically for the hottest pixel near the volcano using AVO's "Okmok Algorithm", beginning on February 18th. Maximum band 3 temperature (the sensor saturates at approximately 50˚C) is given for the area covered by a pixel (1.1 km square). These observations of large, positive, near saturation, short-term fluctuations in satellite-temperatures may be a characteristic of strombolian activity. Low temperature spikes are caused by clouds.

approximately 100 km long was observed blowing to the SSE.

Sheveluch Volcano

On 12 April, an ash poor plume was observed in image n15.99102.0753. It was approximately 30 km long, trailing to the east. A few hours later in image n12.99102.1848, a thermal anomaly was observed with a maximum temperature of 5.74 degrees C with a background temperature of –20 degrees C.

Klyuchevskoy

The only activity at this volcano was on the 9 January when a 90 km plume was observed trailing to the southwest on AVHRR image n14.99010.0258. This plume may not have been volcanogenic.

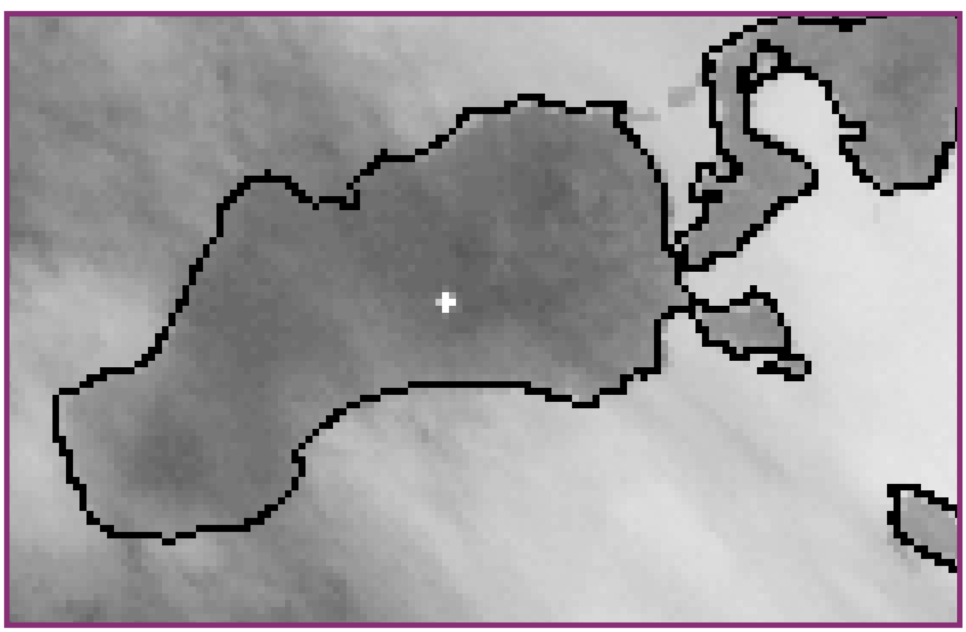

Figure 5. A large thermal anomaly at Shishaldin detected on AVHRR data, 13th March. The zenith angle is low (5.3°), and the anomaly covers four to five pixels in the shape of a cross. The low zenith angle and the shape of the hot spot suggest that the size of the source of the thermal anomaly has increased compared to previous images.

Ken Dean, Jon Dehn, Dave Schneider, Pavel Izbekov and Kevin Engle

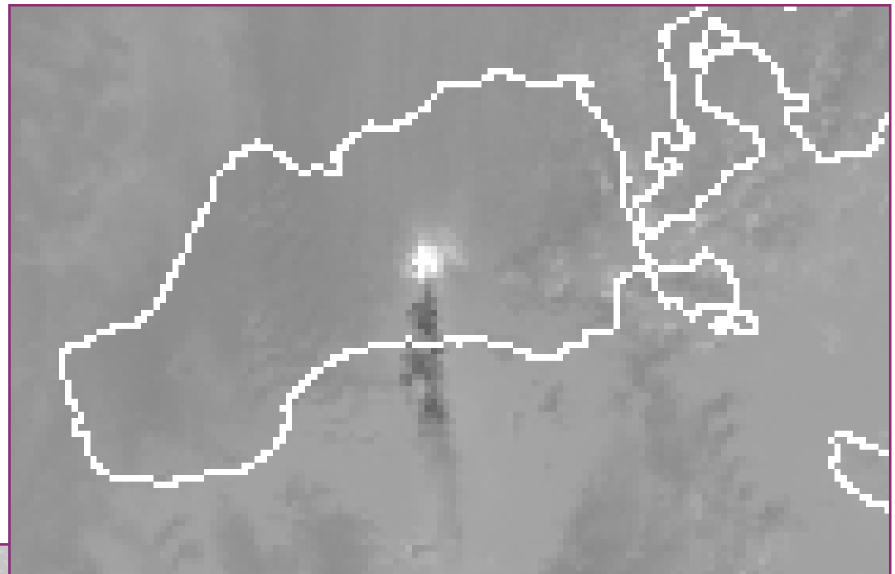

Figure 6: An AVHRR satellite image, 23 April, recorded the largest thermal anomaly observed on satellite data during this eruption of Shishaldin. An ash rich plume is seen trailing to the south. This image was recorded just a few hours prior to the AVO overflight on the 23rd of April where strombolian activity and lahars were observed. The thermal anomaly probably represents warm material on the summit from sustained strombolian eruption. The dense areas in the plume could indicate individual pulses or bursts.

Figure 7: FLIR image of Shishaldin on April 23rd 1999. The white areas are warm. The warm summit (identified as a thermal anomaly on the satellite data in fig. 5) protrudes above the cloud layer. The summit is warmer than the lahars on the slopes. The clouds ringing the summit would obscure or partially obscure the lahars from the satellite imagery.

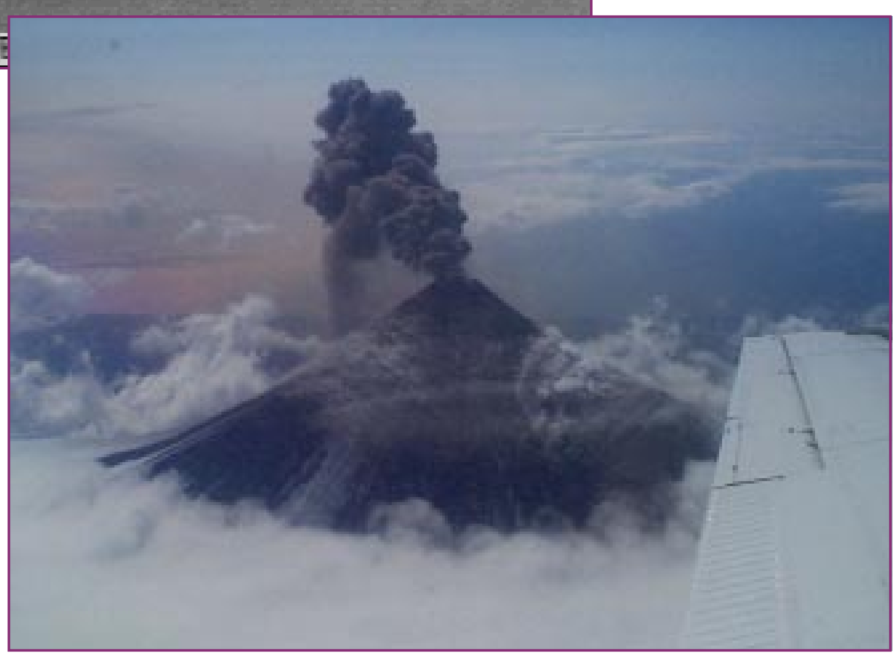

Figure 8: Photo taken during the overflight by AVO staff on April 23rd. The Strombolian activity created small ash laden plumes drifting SE before dissipating within tens of kilometers from the vent. These plumes often detach from the volcano.