Lightning Associated with the August 18, 1992, Eruption of Crater Peak Vent, Mount Spurr Volcano, Alaska

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ABSTRACT

The Alaska Volcano Observatory's lightning detection system detected and located 171 lightning strokes during the August 18, 1992, eruption of the Crater Peak vent of Mount Spurr volcano in Alaska. The strokes, predominantly intracloud, were detected during a 70-minute interval that began more than an hour into the eruption. All detected strokes were of positive polarity. The spatial distribution of the strokes in the horizontal plane defines a ring-like pattern approximately 10 km in diameter and displaced roughly 5 km to the east of Crater Peak. Although lightning was observed during the September 16–17, 1992, eruption of Crater Peak, no lightning was detected by the lightning detection system.

INTRODUCTION

Although the occurrence of lightning in volcanic eruption clouds is well documented, few attempts have been made to use lightning detection and location to monitor eruptions. Such a monitoring approach could potentially allow for the detection of an ash cloud even when meteorological conditions might prevent observations from satellites and ground-based radar. In 1990, the Alaska Volcano Observatory (AVO) experimented with a lightning detection system (LDS) used by the Bureau of Land Management (BLM) in their forest fire program. BLM's network is configured to locate typical meteorologic lightning strikes that could potentially cause forest fires. A subset of BLM's network was modified and configured to enhance the potential to detect and locate volcanogenic lightning caused by the eruptions of Redoubt Volcano, Alaska. The system successfully detected and located volcanogenic lightning during several eruptions (Hoblitt, 1994). In 1991, AVO installed its own LDS and configured it to detect lightning in the Cook Inlet area.

The typical lightning discharge, or flash, is composed of a number of strokes. The series of strokes associated with a lightning flash occur within a few tenths of a second. A lightning discharge is termed a "strike" only if it makes contact with some conductive surface such as the Earth, trees, or aircraft. Each discrete stroke of lightning generates a broadband radio signal that radiates at the speed of light in an omnidirectional pattern.

The LDS at AVO incorporates lightning stroke detectors in the Alaska cities of Palmer, Iliamna, and Homer (fig. 1). These detectors monitor a portion of the radio frequency spectrum for a lightning-induced instantaneous rise in signal amplitude. A stroke that generates a radio signal with an amplitude exceeding the detector's threshold will be recorded at each detector at a different instant in time. The time of arrival of a signal is measured and recorded to submicrosecond resolution. Using these precise times of arrival and the known locations of the detector sites, a lightning stroke's location can be determined.

A central analyzer in Anchorage calculates the locations of strokes. Communication between the analyzer and the remote detectors is via modem and phoneline (fig. 2). At regular intervals, the central analyzer automatically dials and queries each of the three remote detectors. Data is downloaded by the central analyzer and quickly correlated to determine if lightning strokes were detected. Various parameters are determined for each stroke including amplitude, polarity, and location.

There are two primary modes of recording LDS data: in a log file, and in the video information system (VIS). Processed and raw data (including system-status reports) are automatically transferred to and

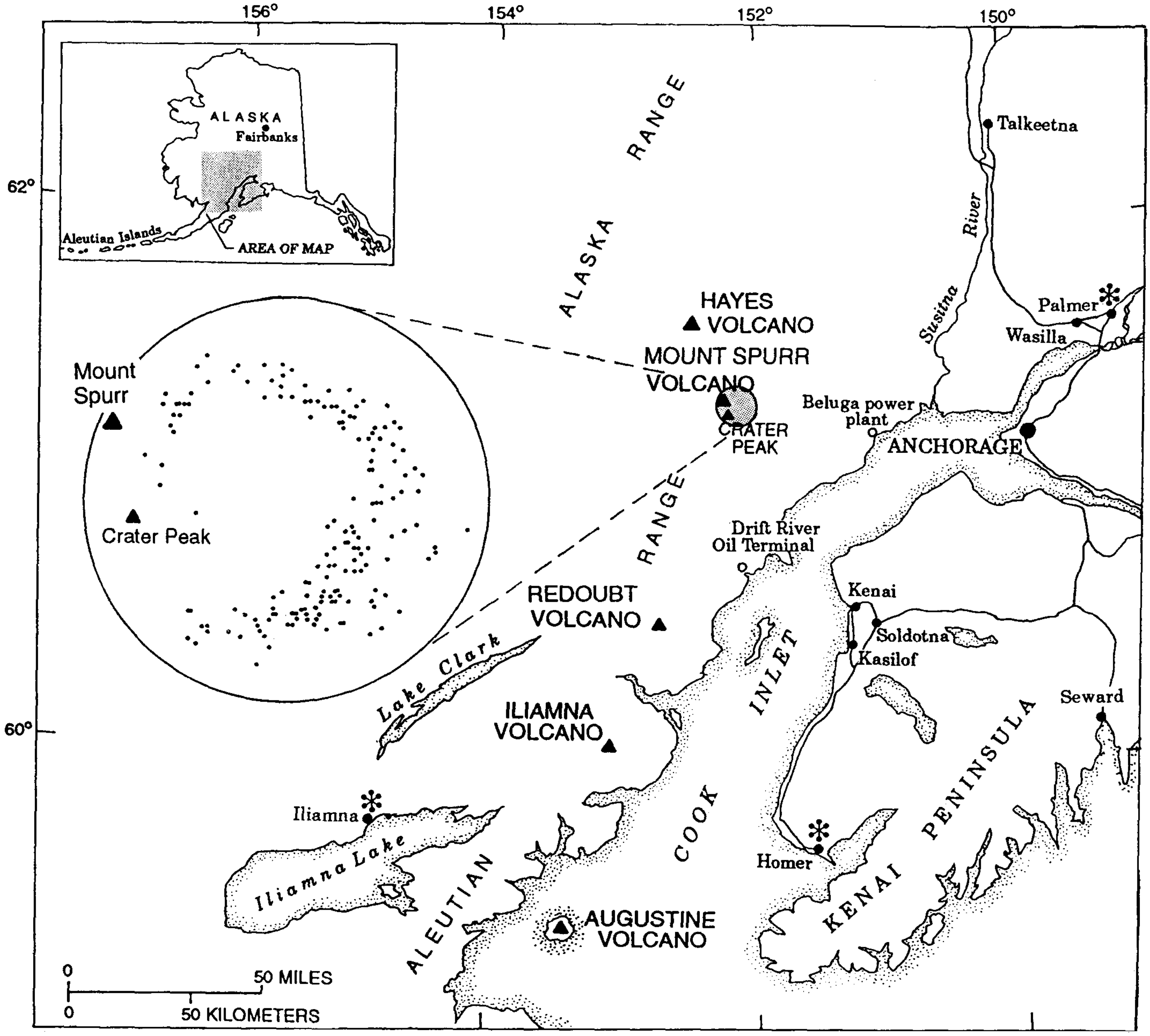

Figure 1. Cook Inlet area and locations of the active volcanoes. Asterisks show locations of LDS receivers. Enlarged view (inset) of area surrounding Mount *Spurr* shows 171 lightning strokes.

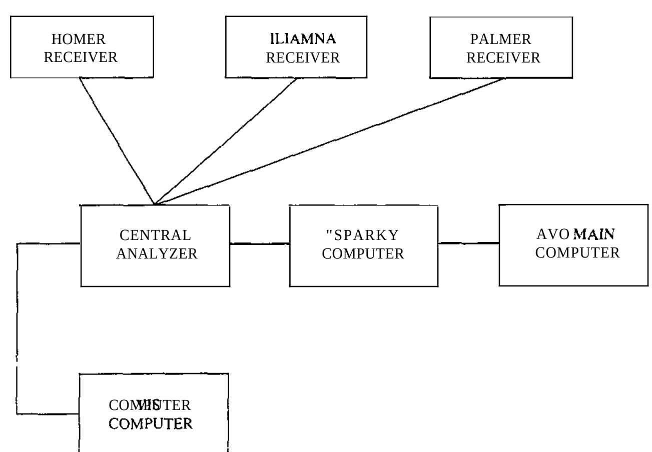

Figure 2. Data storage and communication links for Alaska Volcano Observatory's (AVO) lightning detection system. The central analyzer queries (via modem and phone line) each remote receiver at user-defined intervals. Incoming data are stored in the central analyzer and the computer named "Sparky." Data can be manipulated and viewed graphically through the video information system (VIS) and the AVO main computer.

stored in a log file on an associated computer. This file essentially contains the entire central analyzer output. The VIS data are initially stored in a buffer in the central analyzer. Before lightning data are sent to the VIS, a stroke must meet the criteria of being regionally comparable to, and occurring within 5 minutes of a preceding stroke. These criteria are designed to ensure the reliability of data. The VIS provides a graphic display of stroke locations and allows access to various quantitative stroke parameters.

THE 1992 ERUPTIONS OF CRATER PEAK

Mount Spurr volcano is located 125 km west of Anchorage at the northeastern end of the Aleutian arc (fig. 1). Following 10 months of elevated seismicity, the volcano erupted explosively on June 27, August 18, and September 16–17, 1992. The site of the three eruptions was Crater Peak, a satellite cone at 2,300 m elevation on the southern margin of the caldera and 3.2 km south of Mount Spurr's summit cone (Nye and Turner, 1990).

The three eruptions of Crater Peak were similar in character. The eruptions were explosive with sudden and impulsive onsets to each main phase. Duration of the main phase of each eruption were 3.5 to 4 hours, material ejected largely consisted of andesitic tephra, dense-rock equivalent erupted volumes for each of the eruptions were similar (Neal and others, this volume), and maximum radar-discernible column heights were approximately 13 to 15 km above sea level (Rose and others, this volume).

LIGHTNING RECORDED DURING THE AUGUST 18 ERUPTION

Although lightning was visually observed during the August and September eruptions, the LDS recorded lightning only during the August 18 eruption. The main phase of the August 18 eruption began at 4:42 p.m. Alaska daylight time (ADT). The LDS was unable to establish communication with the detector at Iliamna and therefore was not fully operational prior to 6:30 p.m. ADT. This prevented direct comparison of the onset of the eruption with the onset of lightning. Although the LDS first detected and located lightning at 6:30 p.m. ADT, it is known that lightning did occur before this time. First, an independent LDS operated by the BLM and designed to detect only ground strokes, or strikes, recorded 14 strikes associated with the eruption between 5:43 p.m. ADT and 7:51 p.m. ADT (Keith Pollock, BLM, oral commun., 1992). Secondly, the two operational detectors at Homer and Palmer recognized common events believed to be lightning strokes associated with the eruption as early as 5:30 p.m. ADT. Third, airborne observers at the volcano saw lightning at 5:45 p.m. ADT (G. McGimsey, USGS, oral commun., 1992).

Once communication to all three detectors was established, the LDS recorded 171 strokes during a 70-minute interval. The horizontal spatial pattern of recorded stroke locations forms a crude circle roughly 10 km in diameter (fig. 1). There is a concentration of strokes on the eastern side of the circle. The center of the circle of strokes is displaced approximately 5 km in a direction 110° (true north) from the eruptive vent. This displacement is consistent with the migration of the eruption cloud resulting from the westerly winds during the eruption (Neal and others, this volume).

At the time of lightning detection, the eruption column had extended to its maximum altitude of about 14 km on the basis of C-band radar estimates (Rose and others, this volume), or 18 km (unpublished pilot reports). Satellite imagery near this time depicts an elongate plume extending to the east. The National Weather Service's C-band radar provides a cross-sectional view of the plume (not the eruption column) displaced to the east of the vent. The image shows zones that are defined by regions of like particle size (Rose and others, this volume).

The spatial pattern made by the stroke locations is very uniform, which suggests that it is not a random function. Stroke occurrence and location are most likely controlled by concentrations of particle-size fractions or particle densities within the plume that in turn control charge densities and polarities.

Analyses of stroke signals suggest that more than 70 percent of the strokes were intracloud, and the remaining 30 percent were ground strokes, or strikes. However, caution must be exercised when considering the distinction between these intracloud and cloud-to-ground strokes. The LDS determines stroke type with a model that is based on typical meteorologic lightning. The time between peak stroke signal and the first polarity change is measured. If this time interval is less than 10 microseconds, the stroke is classified as intracloud. If the time interval exceeds 10 microseconds, a ground stroke is indicated. However, volcanogenic lightning might behave quite differently than meteorologic lightning in this regard. For instance, the conductive ionized channel that precedes volcanogenic lightning could perhaps be a slower path than that for meteorologic lightning (Rodney Bent, Atmospheric Research Systems, Inc., oral commun., 1992). If this were the case, some volcanogenic intracloud strokes could be misclassified as ground strokes.

Stroke amplitudes, calculated by AVO's central analyzer, for the 50 detected ground strokes ranged from 15 kA to 40 kA with an average amplitude of 22 kA. These values fall within the range of ground strokes observed in local area thunderstorms but approach neither the low nor high values that describe this observed range (3.5 kA to 350 kA). The LDS is unable to calculate amplitudes for intracloud strokes.

UNDETECTED LIGHTNING

Lightning was neither detected nor observed during the June eruption. Although the occurrence of lightning was observed during the September eruption, none was detected by the LDS even though the system appeared to be operational. Indeed, the system probably did not detect all of the lightning that occurred during the August 18 eruption, even when the system was fully operational. There are several possibilities for this. The simplest explanation is that the signal from intracloud lightning has a lower amplitude than cloud-to-ground lightning. Data from the August 18 eruption indicate that intracloud lightning predominates. Possibly the typical signal levels from these strokes fall below the detection threshold of the LDS. The subset of strokes recorded for the August 18 eruption may have produced greater signal strengths and were therefore the only ones detected.

Considering the similarities between the three eruptions, it is puzzling that strokes were detected for only the August eruption. Perhaps subtle factors are involved in an eruption that would raise the stroke amplitudes or affect other stroke characteristics that would allow for detection. Also, atmospheric and meteorologic conditions at the time of an eruption may influence volcanogenic lightning characteristics.

SUMMARY

An LDS was installed at AVO to further explore the potential to determine the occurrence of volcanic ash clouds through the detection of associated lightning. Such a monitoring approach would allow for the detection of an ash cloud even when meteorologic conditions might prevent observation from satellites and ground-based radar. During one of the three 1992 Crater Peak eruptions, it was demonstrated that the system could function as anticipated. The LDS was able to detect and locate at least a subset of the lightning associated with the August 18 eruption. The circular pattern of the stroke locations give an indication of both size and movement of the ash cloud.

Although lightning was observed during the September eruption, none was detected by the LDS. The LDS did not record all of the lightning associated with the August eruption. A plausible explanation for this is that the relatively low-amplitude intracloud lightning that was predominant during these eruptions did not, with the exception of the 171 lightning strokes recorded during the August eruption, generate strong enough signals to be detected at all three detector locations. Installing a fourth detector closer to the monitored volcanoes may enhance the ability to detect volcanogenic lightning during future eruptions of Cook Inlet volcanoes.

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