A Volcano Rekindled: The Renewed Eruption of Mount St. Helens, 2004–2006
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Chapter 3

Near-Real-Time Information Products for Mount St. Helens—Tracking the Ongoing Eruption

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Abstract

The rapid onset of energetic seismicity on September 23, 2004, at Mount St. Helens caused seismologists at the Pacific Northwest Seismic Network and the Cascades Volcano Observatory to quickly improve and develop techniques that summarized and displayed seismic parameters for use by scientists and the general public. Such techniques included webicorders (Web-based helicorder-like displays), graphs showing RSAM (real-time seismic amplitude measurements), RMS (root-mean-square) plots, spectrograms, location maps, automated seismic-event detectors, focal mechanism solutions, automated approximations of earthquake magnitudes, RSAM-based alarms, and time-depth plots for seismic events. Many of these visual-information products were made available publicly as Web pages generated and updated routinely. The graphs and maps included short written text that explained the concepts behind them, which increased their value to the nonseismologic community that was tracking the eruption. Laypeople could read online summaries of the scientific interpretations and, if they chose, review some of the basic data, thereby providing a better understanding of the data used by scientists to make interpretations about ongoing eruptive activity, as well as a better understanding of how scientists worked to monitor the volcano.

Introduction

The renewed activity of Mount St. Helens, which started in September 2004, caused the Pacific Northwest Seismic Network (PNSN) and the U.S. Geological Survey's Cascades Volcano Observatory (CVO) to rapidly adjust routine monitoring procedures and activities in order to accommodate additional data volume, data types, and real-time monitoring requirements. The speed with which the precursory earthquake swarm developed, the sheer number of earthquakes involved, and the need for rapid analysis and interpretation resulted in many changes being made to what had become routine processing procedures developed over the preceding years. The goal of providing accurate and timely interpretation of the evolving sequence was driven by the need of the emergency-response community to mitigate possible hazards and by intense public interest, as indicated by the horde of media that descended on any site where information might be available (Driedger and others, this volume, chap. 24). Through the precursory seismic swarm, the initial minor explosions, and the subsequent dome-building phase, seismic processing and display techniques were developed or expanded to help provide relevant information to the wide variety of users. This paper documents these techniques, focusing on why and how they were developed and what they contributed at the time to monitoring efforts.

Preexistence of Webicorders

Following the end of the previous eruption of Mount St. Helens in October 1986, seismicity at the volcano was monitored using standard seismic techniques, including earthquake locations and visual monitoring of continuous seismic records in the form of helicorders and webicorders. Data from 12 short-period, analog seismic stations were telemetered to the Pacific Northwest Seismic Network (PNSN) headquarters at the University of Washington (UW) for recording and analysis. A subset was also telemetered to the Cascades Volcano Observatory (CVO) for monitoring purposes.

The PNSN routinely processed events from Mount St. Helens through an event-triggered recording system as part

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of the routine catalog generation for the whole Pacific Northwest. These catalogs were originally only released in quarterly reports and distributed by surface mail. With the rapid evolution of the World-Wide Web, in the early 1990s the PNSN created a public Web site (www.pnsn.org) for online distribution of epicenter catalogs, maps, and other derived information products on earthquakes and volcanoes. As is common for many seismic networks, the PNSN also provided near-real-time Web images of selected seismograms, referred to as webicorder plots (fig. 1).

By 2004, webicorder plots were being produced for more than 60 of the approximately 250 PNSN seismic stations, including several Mount St. Helens stations. As soon as seismic unrest was recognized at Mount St. Helens (September 23, 2004), additional stations there were added to the volcano webicorder list at the expense of stations at other volcanoes; processing constraints limited the total number of webicorders that could be accommodated at any one time.

The webicorder plots were quickly discovered by many members of the public. By September 28, the number of hits on the PNSN departmental Web server was causing a substantial slowing of computer processing and increased Web-page delivery times. Because of the obvious public interest and the PNSN's mission to provide near-real-time information to the public, the PNSN requested assistance from the University of Washington Computers and Communications (CAC) group. Within 18 hours of our request the CAC had a high-capacity Web server connected directly to external high-volume routers to mirror our main pages. Within a few days this server was servicing requests at rates as high as 250,000 per hour, and the CAC group expanded the system to dual server machines with load-balancing routing. The first week's activity totaled more

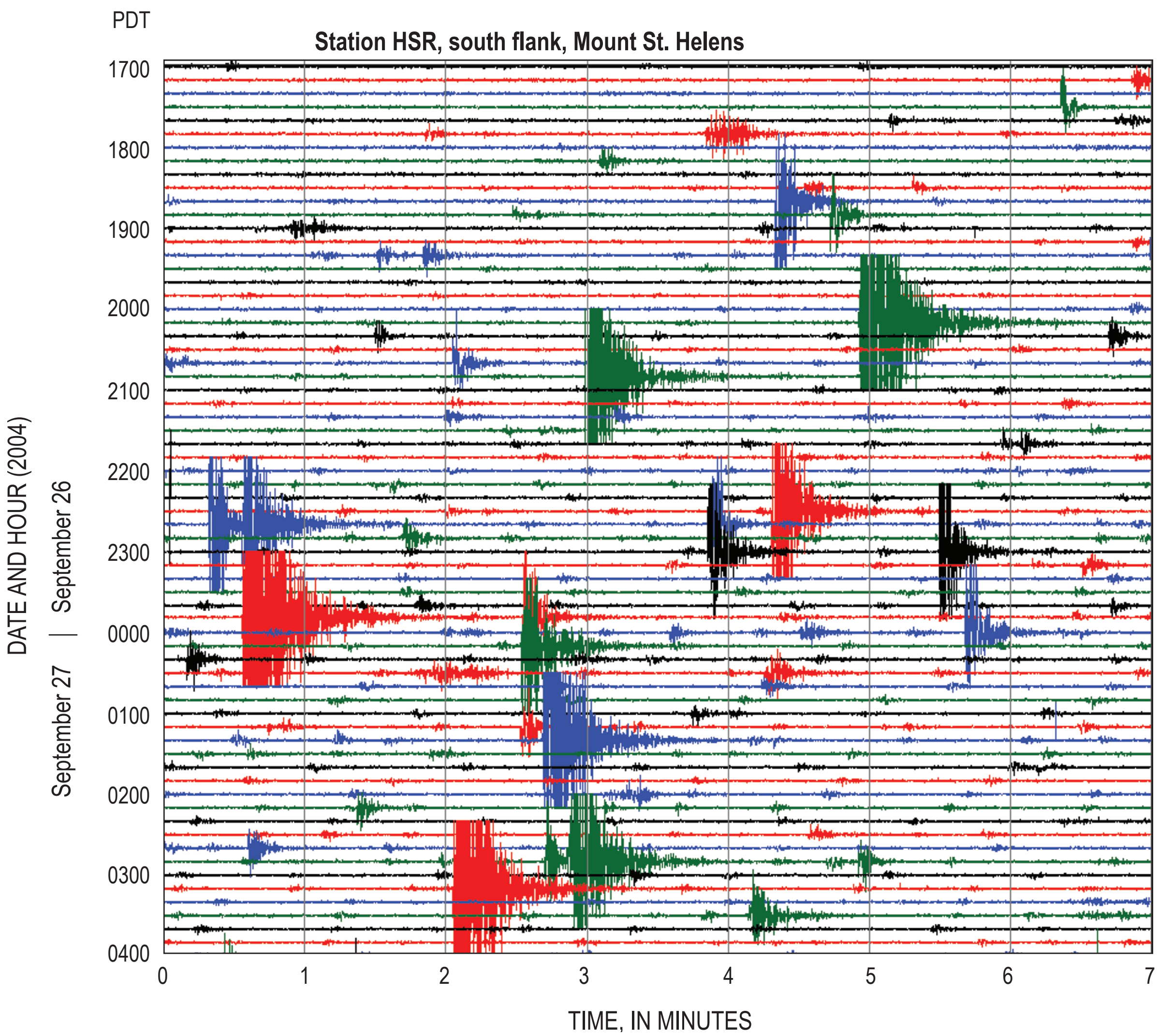

Figure 1. Part of a webicorder plot from station HSR on the south flank of Mount St. Helens from September 26 and 27, 2004. Time advances from left to right and top to bottom, as if reading a book. Each line begins a new 10-minute cycle (the last 3 minutes of each cycle are clipped off here), and gray vertical lines mark 1-minute intervals; color variations are merely to aid the eye in separating traces. Webicorder plots such as this one were updated in real time, available online before and during the 2004 restlessness and ensuing eruption, and were very popular with the public.

than 23 million hits, which translates to roughly 5 million complete pages of information served.

In addition to establishing a mirror site, the PNSN also established a semiprivate (nonlinked but otherwise open) Web server for use by the scientific staff at UW, CVO, and other institutions involved in monitoring the evolving crisis. A password-protected Web server at CVO hosted additional webicorders and other seismicity-related plots. The mix of public and private Web servers enabled us to satisfy the public's need for information while maintaining real-time data-sharing capabilities between CVO and the PNSN. Given the physical separation between the PNSN (located in Seattle, Wash.) and CVO (290 km south in Vancouver, Wash.), the capability for real-time data sharing was critical for effective telephone discussions between CVO and UW staff regarding the evolution of the unrest and eruption.

Real-Time Seismic Amplitude Measurements (RSAM)

Webicorders were valuable for seismologists to qualitatively gauge changes in event type, frequency, and size over the previous minutes to hours, but other tools were necessary to provide a quantitative basis for tracking seismicity changes through time. One such tool, which was quickly implemented at CVO (September 23), was the plotting of real-time seismic amplitude measurement (RSAM) values (Endo and Murray, 1991) (fig. 2). RSAM plots show the rectified amplitude of ground motion averaged over specified time intervals, commonly 10 minutes. Rather than focusing on individual events, RSAM provides a simplified but useful measure of the overall level of seismic activity. RSAM has become a widely used tool in volcano observatories around the world because it readily and quantitatively reflects changes in number and size of earthquakes, tremor, and background noise, each or all of which may be related to changes in volcanic activity. As a result of their previous widespread use, RSAM plots were generally well understood by all scientists at CVO and the PNSN.

The Earthworm seismic-data acquisition and processing system (Johnson and others, 1995; U.S. Geological Survey, 2006) is used both at CVO and at UW for the collection and analysis of seismic data. The "ew2rsam" module, a part of the Earthworm system, was used in the Mount St. Helens crisis to generate RSAM values in real time and plot them on multistation graphs at intervals ranging from several days to several months. Such multistation plots make it easier to determine whether seismic-amplitude changes result from local effects at each station (such as wind noise) or from volcanic processes. The RSAM plots were particularly important for recognizing trends when seismicity intensified on September 26, because webicorder plots for stations on or near the edifice became increasingly saturated and difficult to interpret (Moran and others, this volume, chap. 2).

Root-Mean-Square (RMS) Plots

The usefulness of the RSAM plots inspired the creation at the PNSN of root-mean-square (RMS) plots (fig. 2). Rather than just plotting the average of the rectified signal, these plots show the square root of the sum of squares of the signal averaged over fixed time intervals. Also, different plotting styles for the CVO RSAM and the PNSN RMS were used to emphasize different aspects of seismicity changes. Whereas the RSAM plots connect the points of each average with a line, the RMS plots just show individual averages over a fixed window length as isolated points. Such plots were routinely made for averaging windows of 1 minute and 10 minutes and posted

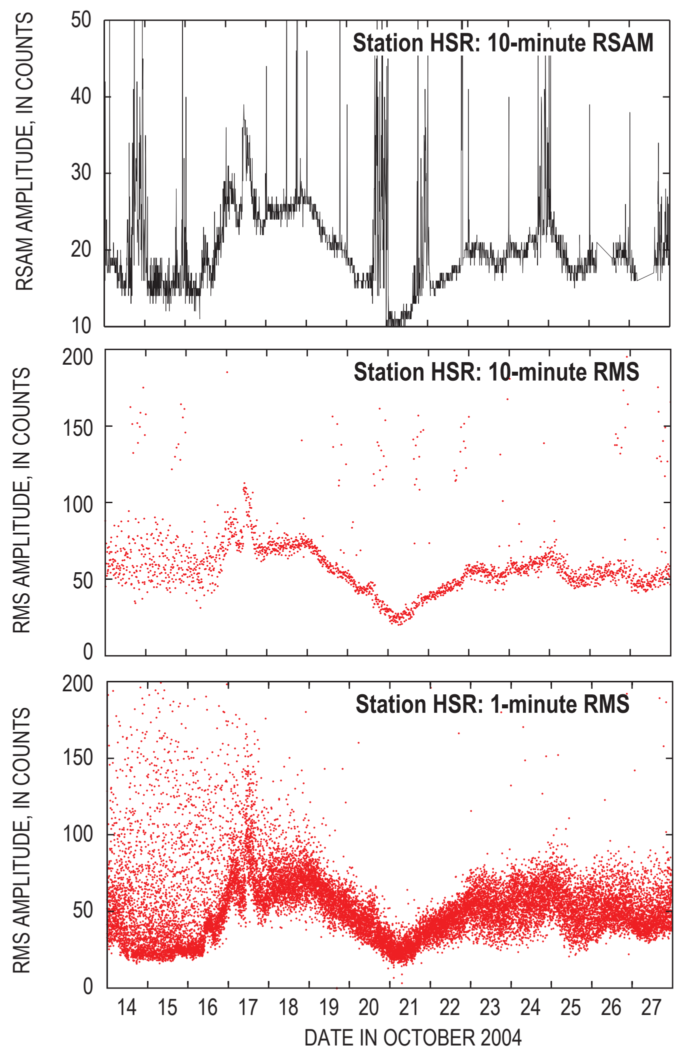

Figure 2. Real-time seismic amplitude measurement (RSAM, top) and root-mean-square (RMS, middle and bottom) plots for seismic signal levels from station HSR during mid- to late October 2004, early in the eruption. Besides the different algorithm to generate the points, plotting characteristics are also different to emphasize different aspects of the activity. Note how the 10-minute and 1-minute RMS plots differ in resolution for the variability of seismic activity.

in nearly real time on the PNSN public Web page. Although the RSAM and RMS plots generally show similar trends, the RMS plots can isolate changes caused by a few large events from cases in which there were an increased number of moderate-size events. From what we know, the inclusion of these plots on the PNSN public Web pages was the first time anywhere that reduced data, other than earthquake locations, were automatically released to the public in real time over the course of a volcanic eruption.

A modification of the RMS plotting routine was developed later in the eruption to show the largest and smallest RMS values determined over a specific time interval. For these plots, RMS values were computed every 5 s and only the largest and smallest during a 30-minute period were selected to plot. In effect these plots track the largest earthquakes and the lowest background level. The maximum-value RMS plots were used for tracking changes in maximum earthquake size over periods of days to weeks, whereas the minimum-value RMS plots were used for detecting elevated background levels that could have represented volcanic tremor (fig. 3).

Spectrograms

Spectrograms, sometimes called “Seismic Spectral Amplitude Measurements” (SSAM) (Rogers and Stephens, 1995) are plots of signal frequency versus time in which color or intensity is used to display the relative strength of a signal in a frequency band (fig. 4). Seismic spectrograms are generated by taking the Fourier spectrum of a fixed time window of signal (1 minute on 12-hour spectrograms at UW and 2.5 s on 10-minute spectrograms at CVO), smoothing the spectrum, and then plotting the amplitude as a color (warm for high amplitude, cool for low) on the vertical frequency axis.

Spectrograms for different sets of stations were being created at UW (12 hours per plot) and at CVO (10 minutes per plot) before September 23, 2004. The spectrograms added little to the interpretation of event types in the first few days of the seismic buildup. By September 26, however, they became useful for recognizing the decrease in higher frequencies as the earthquake sequence progressed from predominantly volcano-tectonic events, with their wide spectrum, through hybrids to dominantly low-frequency events, described by some as long-period (LP) events (Moran and others, this volume, chap. 2; Thelen and others, this volume, chap. 4). These changes of earthquake character were obvious on seismograms of individual events, but the spectrograms allowed us to track changes over time as well. Spectrograms also aided in distinguishing rockfalls, which have broad spectra and long durations, from small, emergent earthquakes. Spectrograms have continued to play an important role in the subsequent years of dome building, because they display variations in seismicity that correspond to different types of events.

Event Processing

At the PNSN, locations and magnitudes of earthquakes in the Pacific Northwest are routinely determined by manual review of waveforms selected by the Earthworm automatic event-triggering-and-recording system. This system uses a detector algorithm that determines a station “trigger” based on the ratio of short-term average over long-term average (STA/LTA) exceeding a specific threshold. Several station triggers must be active at roughly the same time from a subnetwork of nearby stations for the system to declare an event. This criterion helps to discriminate seismic events of real interest from noise bursts on individual stations. The triggering algorithm is tuned to be sensitive, so that very few events of interest are missed, at the cost of having many false triggers. Such a triggering system, in one form or another, has worked well since 1980, having detected for processing more than 100,000 earthquakes between 1980 and 2004.

With the onset of the Mount St. Helens seismic swarm in late September 2004, the routine processing procedures for the PNSN quickly were swamped with data. The automatic system triggered and recorded the early earthquakes with magnitudes as small as $M_d = -1.0$. Event trigger-

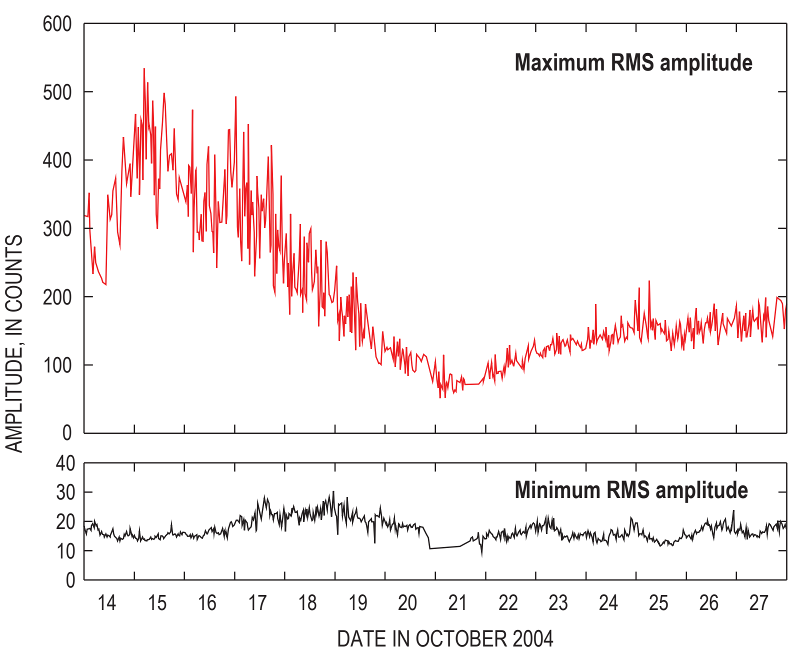

Figure 3. Maximum root-mean-square (RMS, top) and minimum RMS (bottom) plots for seismic-signal levels from station HSR during mid- to late October 2004, early in the eruption. Time period same as in figure 2. Minimum RMS shows background levels, which increased and diminished over roughly weekly intervals. Maximum RMS shows a substantial decrease in large earthquakes during this period.

ing rates for the whole network went from an average of 2–5 events per hour (more than 50 percent noise triggers) before the swarm onset to 6–10 per hour by the end of the second day and to 25–40 per hour by the end of the third day. Soon thereafter the system was in an almost continuously triggered state. By the end of the second day, more than 250 events had been processed, and by the third day the analysis staff could not keep up with manually processing all triggered events. In addition to the burden of reviewing the triggered events, the volume of waveform data was filling available disk space, forcing us to move unprocessed data to tape and other media. Triage was necessary to ensure that at least a reasonable sampling of events were manually reviewed and that no trace data were lost. The task was twofold: first, we trained additional staff and students in the basic process and divided review tasks among them; then we experimented with different trigger parameters to achieve a representative, but not complete selection of events for manual processing.

After the first two months, with seismic activity continuing at a fairly high rate and the potential for a long-lasting eruption becoming evident, we changed the procedures in such a way that we could review the data for significant changes but process in detail only a selection of the larger or impulsive events. For this we started generating hour-long, sequential artificial trigger files of only Mount St. Helens stations, with a display order based on distance from the vent so that the waveforms could be easily scanned for events of interest and for changes in event or background signal characteristics. The trigger threshold for the automatic triggering system was raised for the Mount St. Helens subnet so that only larger events would generate a complete event trigger. This procedure sped up the routine analysis and provided a better way of detecting subtle changes in event types or characteristics, because an analyst could quickly scan through all of the data and easily see changes in both large and small events.

The hypocenter distribution determined by standard processing of well-recorded earthquakes changed very little over the course of the seismic restlessness and ensuing eruptive sequence. Hypocenter depths decreased during the first two weeks of restlessness from 2–3 km deep to less than 1 km. The scatter in epicenters is comparable to variation arising from picking errors. Some of the variation in locations can be attributed to changes in station configuration. Several times during the sequence, no station was located within 1.5 km of the source area because of station outages resulting from explosions, and thus depth control, in particular, was poor. Subsequent specialized analysis shows a much tighter clustering of hypocenters than that determined during the height of the sequence (Thelen and others, this volume, chap. 4).

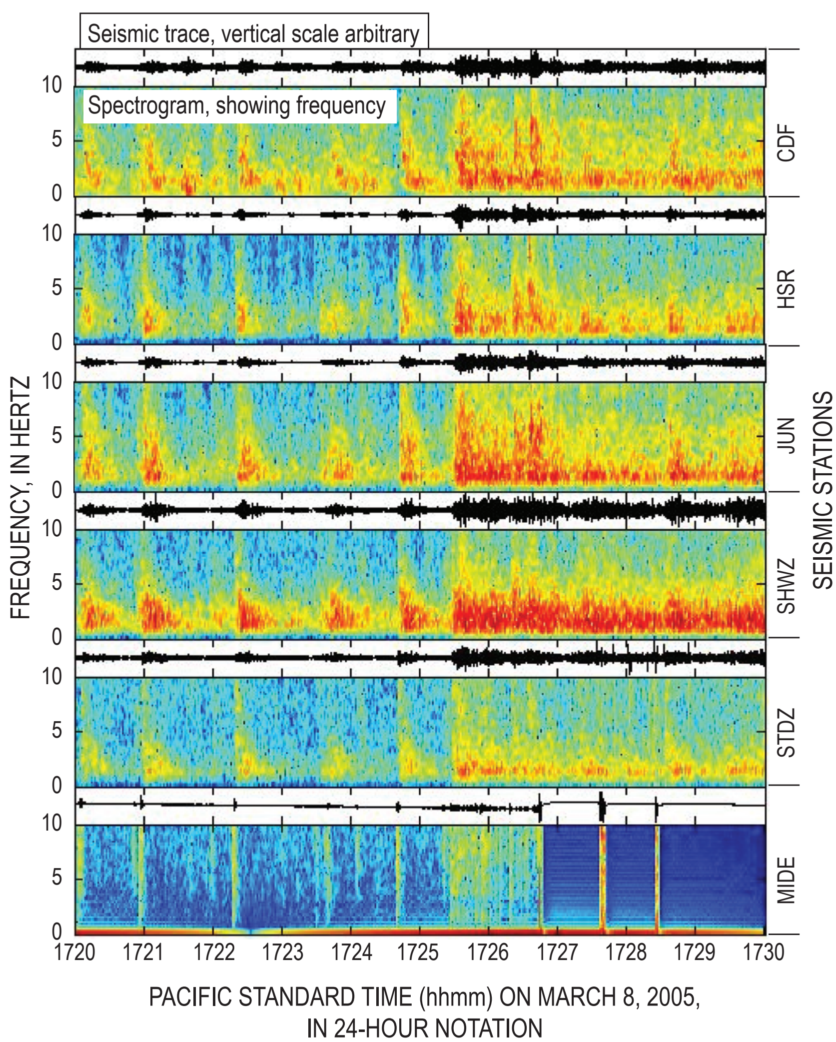

Figure 4. Sample spectrograms from six stations for a 10-minute period on March 8, 2005 (local date). Shown for each station are conventional seismogram (upper line trace) and corresponding spectrogram (color spectrum). Periodic earthquakes characterize the record until about 17:25:30 (1:25:30 UTC), when an explosion at the vent marks onset of sustained, low-frequency tremor. Station MIDE, lowermost of graphs, lost signal sporadically and then completely, owing to thick, airborne ash that interrupted radio transmission.

Automatic Trace Processing

Once it became apparent that the dominant seismic signals were from very regular earthquakes—so regular that they were named “drumbeat” earthquakes—we felt a need for tools to track the rate and type of individual earthquakes. A modification of an event-triggering algorithm was developed to detect characteristics of individual events. This algorithm was based on a ratio of short-term and long-term averages of RMS values computed at 5-s intervals for a key subset of close-in stations with good signal-to-noise ratios. The onset of an event was reliably detected, but determining the end of one event so that the algorithm would de-trigger and be ready for the next event required some tuning of parameters. Once an event was declared, several parameters, including its peak amplitude, average RMS value, and peak frequency, were determined from the original waveforms. The event was not located in the traditional sense, but an effective automatic event catalog was generated that included time, size, and general frequency content.

Focal Mechanisms

Focal mechanisms are traditionally difficult to obtain in volcanic areas because the emergent arrivals typical of low-frequency earthquakes and the high attenuation within the edifice result in low signal-to-noise ratios at more distant stations. Additionally, at Mount St. Helens, earthquakes located at shallow depth in the edifice are mostly small, contributing to poor signal-to-noise ratios. Shallow hypocenters mean that sampling the entire focal sphere, a requirement for a well-constrained focal mechanism, is difficult. Determination of focal mechanisms is therefore restricted to the relatively few large events for which good first motions are available on many stations. Typically focal mechanisms were generated at the PNSN during the event-location process by picking polarities (up or down) of the first motion. A modification of the program "FPFIT"(Reasenberg and Oppenheimer, 1985) was used to fit focal planes for a double-couple solution when there were 10 or more picked polarities. An unusual aspect of Mount St. Helens earthquakes is that a vast majority of first motions are dilatations. Many events have dilatations on all stations, giving the impression of an implosive or tensile source. However, because of poor sampling of the focal sphere, it is sometimes possible to fit a double-couple solution even to these cases. Figure 5 shows examples of four typical events with predominantly "all down" first motions. Of these four events only one clearly does not have a possible double couple solution.

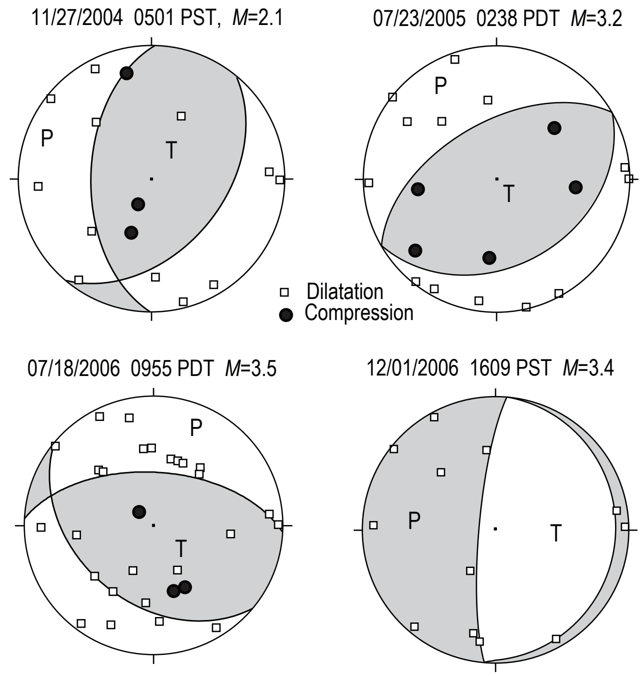

Figure 5. Examples of focal mechanisms determined from four of the many larger, well-recorded events. All such events are located within a few hundred meters of the vent. Note that while almost all polarities are dilatations, double-couple solutions can be fit in some cases. In other cases, such as the event of July 18, 2006, no double-couple solution is possible without many (five) inconsistent polarities.

Event Magnitudes

Routine earthquake processing by the PNSN uses coda duration to compute magnitudes (Crosson, 1972). For most tectonic earthquakes a consistent linear relation exists between the log of the coda duration and the local magnitude, M_L. However, this relation breaks down for earthquakes recorded on Cascade Range volcanoes. For shallow earthquakes in particular, the coda duration is much longer than expected for a given magnitude. Two calibrated broadband stations were installed near Mount St. Helens in October 2004, early in the eruption (McChesney and others, this volume, chap. 7). By deconvolving their known instrument responses and then convolving a Wood-Anderson response, equivalent maximum-trace amplitudes on standardized Wood-Anderson seismograms could be calculated. The resulting local magnitude (M_L) was determined for a suite of earthquakes over the magnitude range 0.5–3.4 (fig. 6). Coda durations for the larger events, mostly picked on stations distant from the volcano, gave duration magnitudes (M_d) comparable to the local magnitude (M_L). For smaller events, however, M_d is often grossly overestimated owing to the extended codas generated by the volcanic earthquakes recorded at stations on volcanic rocks.

Even though the coda duration magnitudes overestimate the true magnitude of the earthquake, coda magnitudes were still measured for located earthquakes to give a quantitative measure of the relative sizes of earthquakes at Mount St. Helens. Codas for the calculation of magnitude are measured only on stations off the edifice (beyond a 5-km radius) to minimize the effect of the extended codas.

Special Web Pages

For many years the PNSN Web site has maintained topical Web pages for all of the monitored Cascade Range volcanoes. Besides some general descriptive text for each volcano and links to the more extensive descriptions on CVO Web pages, these pages provide plots of epicenters, depth versus time, and energy release versus time at three different time scales. The plots have always been based on routine processing of earthquakes located at a volcano. During inter-eruption periods and for minor seismic swarms, these pages continue to be useful for seismologists and informative for the general public. As the current seismic sequence escalated, however, the plots often became outdated because the routine processing (and thus the catalog) was greatly delayed or incomplete. Thus the utility of these special pages to assist in the interpretation of changes was severely compromised. The automatic RSAM and RMS plots quickly became favored as the data product most used for tracking changes in the seismicity at Mount St. Helens. However, public interest in the special pages remained high, even though we frequently posted disclaimers concerning the accuracy and completeness of these plots.

By adopting the changes already described in this paper, earthquake processing again became routine enough that the special volcano-related pages for Mount St. Helens represented a near-real-time picture of seismicity, even though only a fraction of detected earthquakes were logged in the catalog of located events. For example, time-depth plots (fig. 7) of located events eventually made it obvious that the depths of earthquakes taking place beneath Mount St. Helens since the 1980s changed dramatically with the advent of the 2004 eruption. Earthquakes at depth of 2–3 km, with occasional deeper swarms, had been the norm at Mount St. Helens since the late 1980s. These events, particularly the deeper swarms, were interpreted as representing the repressurization of the magmatic system by recharge (Moran, 1994; Musumeci and others, 2002). With the advent of the 2004 (and ongoing) eruption, these deeper events ceased. This depth-pattern shift hints that if magma recharge is continuing during the eruption, it is not pressurizing the deeper system.

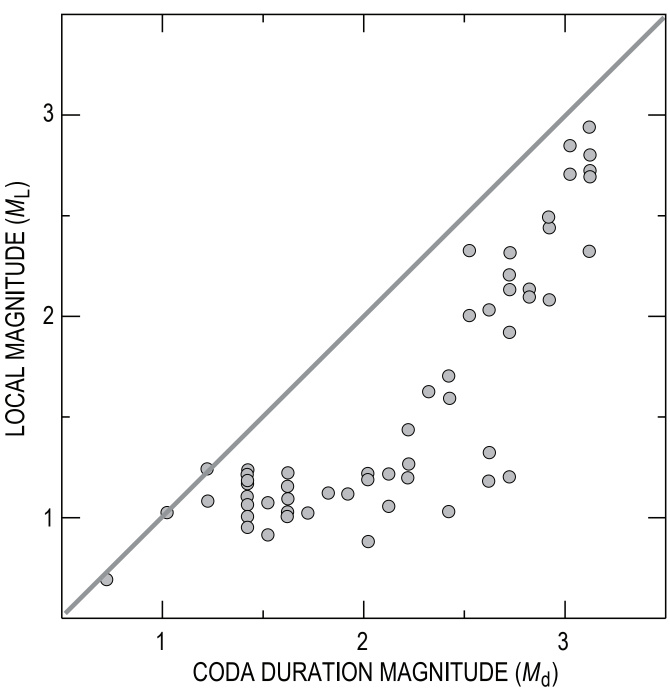

Figure 6. Coda duration magnitude versus local magnitude for a selection of Mount St. Helens earthquakes illustrates how use of coda duration magnitudes overestimates the local magnitudes for these earthquakes, particularly at lower magnitudes.

RSAM Alarms

In addition to magnitude-based earthquake alarms routinely used by the PNSN, several eruption-specific alarms were developed by CVO during the first 6 months of the eruption. RSAM alarms tuned to detect both large, discrete events (“event alarm”) and smaller amplitude but longer duration events (“tremor alarm”) were employed by CVO in mid-October 2004, shortly after the end of intense seismicity accompanying the vent-clearing phase. These alarms had previously been developed by the USGS Volcano Disaster Assistance Program as part of the “Glowworm” package of modules that operate as an add-on to the Earthworm acquisition system (Marso and others, 2003a). Before 2004, RSAM alarms had been used for more than a year to monitor the eruption of Anatahan volcano in the Commonwealth of the Northern Mariana Islands (Marso and others, 2003b).

The “event alarm” tracks RSAM values determined over a 2.56-s window (for 100-Hz data), with alarms issued if thresholds are exceeded at a prescribed number of stations for longer than 8 s. The “tremor alarm” uses RSAM values for 1-minute windows. When an alarm is issued, a separate module sends alerts via Short Message Service (SMS) to cell phones carried by on-call scientists. A potential weak link in this chain is the use of SMS, which requires that e-mail servers and SMS services be fully functional. Alerts were occasionally delayed by several minutes or even an hour before reaching individual phones. To partly address this limitation, SMS messages were sent to multiple cell phones (13 as of the summer of 2006) using multiple carriers. Nevertheless, these problems kept us from relying completely on SMS messaging, which we augmented by periodic data checks during off-hours.

Alert thresholds for the “event” and “tremor” alarms required refinement throughout the first 6 months of the eruption. Seismicity was so energetic initially that the alarms had to be desensitized to minimize the number of alerts. In mid-November 2004, larger earthquakes began occurring daily (Moran and others, this volume, chap. 2), and the “event alarm” was set so that thresholds were just barely exceeded by these events. Thresholds for the tremor alarm were much harder to determine, as we had no quantitative means for establishing thresholds. They initially were set at nominal values that were sufficiently high to prevent false triggers from wind and other noise sources. As a result, no alarms were issued for the January 16, 2005, explosion, which was accompanied by low-amplitude tremor that was barely detectable on stations outside the crater (Moran and others, this volume, chap. 6). Tremor alarm thresholds were reset on the basis of

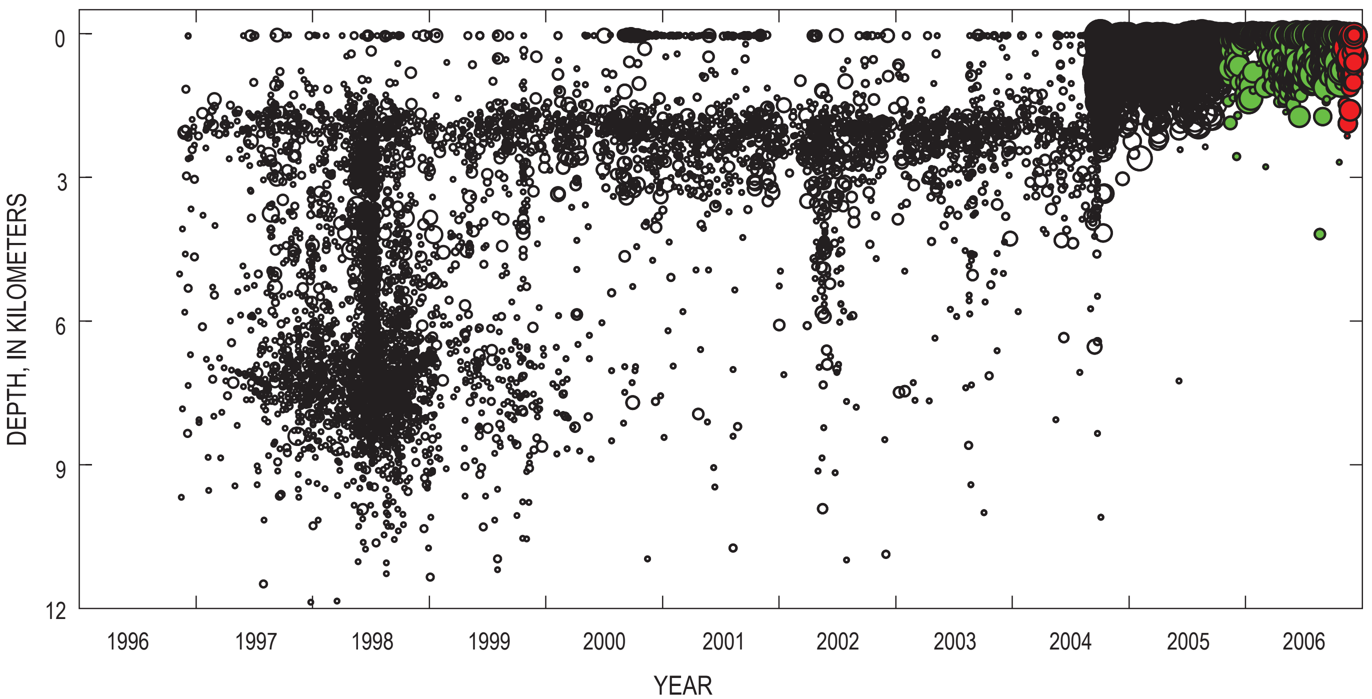

Figure 7. Time versus depth plot for a decade of seismicity at Mount St. Helens. Plot shows approximately 24,000 earthquakes located directly under the volcano (within 6-km radius of the new dome) between January 1997 and the end of 2006. Size of circles is proportional to event magnitude. Green circles, events in 2006; red circles, events in December 2006.

recordings of this explosion on stations located within the crater. However, the closest station became intermittent shortly after the January explosion and had stopped transmitting altogether by the time of the March 8, 2005, explosion. Seismicity associated with the March 8 explosion was more energetic (Moran and others, this volume, chap 6), but thresholds were not exceeded on enough stations to generate an alarm.

The failure of these alarms to generate alerts during explosions motivated us to develop a new alarm in the event of a loss of analog telemetry. Of the six explosions occurring during 2004–5, four, including the January 16 and March 8, 2005, explosions resulted in temporary or permanent loss of telemetry from at least one station. Traditional RSAM alarms have always used RSAM values from which the electronic bias or direct-current (DC) component has been removed, in large part to avoid false alarms resulting from common misalignment problems with analog telemetry circuitry that can impose a small DC offset on seismic data. However, the USGS J120 discriminator includes circuitry that detects the loss of the subcarrier and sets the discriminator output to a static 0.7-V DC level to distinguish loss of telemetry from a quiet seismic signal.

We created a new Earthworm module (based on the Earthworm ew2rsam module) that does not remove the DC component from RSAM values. Named FLOTSAM (not an acronym), this new alarm system sends alerts whenever values exceed a preset threshold at any station. The FLOTSAM system has sent out several alerts, some of which have been generated by loss of telemetry from crater stations destroyed during large rockfalls. Other alerts have resulted from stations that have stopped transmitting because of power outages at the site or weather-related disruptions of the radio signal.

The FLOTSAM alarm has become the alarm that the PNSN and CVO rely upon the most for detecting explosions, because no fine-tuning of amplitude and duration thresholds is required. All that is required is at least one seismometer placed close enough to the vent to have its radio signal disrupted by ash or by physical damage to the station. The event and tremor alarms are employed as well, with the event alarm proving to be a reliable detector of large earthquake-generated rockfalls, which sporadically produce ash clouds that reach from hundreds to several thousand meters above the crater rim.

Real-Time Traces for Remote Use

Early in the Mount St. Helens 2004 eruption, we became aware that researchers at other volcano observatories and academic institutions were interested in our seismic data. Besides the public Web pages, we provided access over the Internet to our real-time trace data wave-servers on a case-by-case basis. We also set up a direct export of selected data to the Alaska Volcano Observatory (AVO), where researchers were interested in following the seismic sequence in detail. At AVO and Stanford University the real-time data integration tool, VALVE (Cervelli and others, 2002), was used to track changes in seismic activity along with other parameters. The seismic-trace display program, SWARM (Alaska Volcano Observatory, 2006) was used at several different institutions to examine continuous seismic waveforms and their frequency content. In particular, researchers at the following institutions became near-real-time collaborators participating to some degree in the interpretation of specific aspects of Mount St. Helens seismicity:

- Alaska Volcano Observatory (Anchorage and Fairbanks) — event character, multiplet analysis
- U.S. Geological Survey (Menlo Park, Calif.) — event character, frequency shift
- University of California, Los Angeles — strong-motion portable monitoring, explosion analysis
- University of Memphis (Tennessee) — broadband portable monitoring
- Los Alamos National Laboratory (New Mexico) — multiplet analysis
- University of New Hampshire — multiplet analysis, acoustic signals.

Public Use and Response

The availability of relatively detailed information on the Web in nearly real time for this eruption of Mount St. Helens provided a new and powerful tool for public understanding. The availability of near-real-time original data (seismic traces) and analyzed products (RMS plots, maps, and time-depth plots) resulted in a change in the public perception of the eruption and their interaction with scientists. In previous eruption crises, the public has learned about the process primarily through the eyes of the news media, who may witness or photograph the physical events and talk with scientists about their interpretations. In this latest eruption of Mount St. Helens, the public could see for themselves on the Web many of the same data and products that the scientists were using. This availability improves the public understanding in two significant ways: Although the public still obtained the basic summary information from the news media, those wanting more or not trustful of the interpretations they were hearing could look at some of the data themselves.

The current eruption of Mount St. Helens is remarkable for the near absence of rumors and conspiracy theories purporting that critical information was being deliberately withheld from the public by scientists and emergency managers. The public also demonstrated the ability to digest a variety of sophisticated information products in order to follow the course of the eruption. Providing rich, open sources of eruption data enabled the public and media to monitor the ongoing eruption and may have encouraged them to seek further clarification from the scientific community when issues of interpretation arose. This public availability limited the kind of wild speculations that have sometimes occurred in the past.

Acknowledgments

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