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Monitoring Cascade Volcanoes

Volcano eruption forecasting relies on several disciplines of volcanology.

Active volcanoes are complex natural systems, and understanding a volcano's behaviors requires the attention of specialists from many science disciplines. It demands a combination of current knowledge about magma systems, tectonic plate motion, volcano deformation, earthquakes, gases, chemistry, volcano histories, processes, and hazards.

Helicopter dropping off monitoring equipment at Mount St. Helens, Washington.

No single tool or technique can adequately monitor or predict volcanic behaviors. Therefore, volcanologists rely on an assortment of instruments and techniques to monitor volcanic unrest. This requires placement of monitoring instruments both close to and far away from the primary source of eruptive activity (e.g. in a crater, on the crater rim, and on the volcano's flanks). By placing sensitive monitoring instruments at hazardous volcanoes in advance of the unrest, the USGS CVO helps to ensure that communities at risk can be forewarned with sufficient time to prepare and implement response plans and mitigation measures. Recommendations for the numbers and types of ground-based sensors were made by an interdisciplinary team of scientists as part of planning for the National Volcano Early Warning System. CVO uses these recommendations to plan monitoring improvements throughout the Cascades.

You can watch interviews with volcano scientists (Web Shorts) about their research and monitoring efforts and videos about volcano monitoring techniques in the Multimedia section of this website.

Cascade volcanoes present unique challenges for volcano monitoring.

The events surrounding the May 18, 1980 eruption of Mount St. Helens helped scientists to recognize some new and subtle patterns of volcanic activity that could help them forecast Cascade volcanoes' eruptions. Since then, tools for tracking the movement of magma beneath Cascade volcanoes have evolved from the use of isolated instruments to dense networks of ground-based sensors that measure earthquakes, swelling of the volcano, and emission of volcanic gases.

Rime ice coats telemetry station north of Mount St. Helens, Washington.

Today, scientists rely upon remote monitoring equipment 24 hours a day and 365 days a year to deliver real-time data to the CVO. When scientists design and install monitoring stations on the Cascade volcanoes, they must consider the remoteness of sites, rough terrain, and wintry conditions. Each monitoring station contains delicate sensors, a power unit, and an antenna that can withstand strong winds, heavy snowpack, and sub-zero temperatures. Just as important to the monitoring devices are telemetry systems designed to transmit data from each volcano to the CVO. The systems are developed to relay radio signals reliably, unimpeded by miles of rugged mountainous terrain.

USGS expands volcano monitoring networks to detect volcanic restlessness.

During the past decade at Cascade volcanoes, USGS and the Pacific Northwest Seismograph Network (PNSN) have expanded monitoring networks on Mount St. Helens, Mount Rainier, Mount Hood, Newberry

Volcano, and Crater Lake. CVO currently has plans in development to augment sparse monitoring on other hazardous Cascade volcanoes including Mount Baker and Glacier Peak. You might see these instruments on a volcano's slopes; please know that they are hard at work for communities downwind and downstream of the volcano.

SWFL seismic station, on the crater rim of Mount St. Helens, was replaced on Aug 8, 2013 with SWF2 at a lower elevation.

To see the monitoring data for specific volcanoes within the Cascades Volcano Observatory area of responsibility, follow the links below.

Oregon volcanoes

Mount Hood
Mount Jefferson
Newberry
Three Sisters
Crater Lake

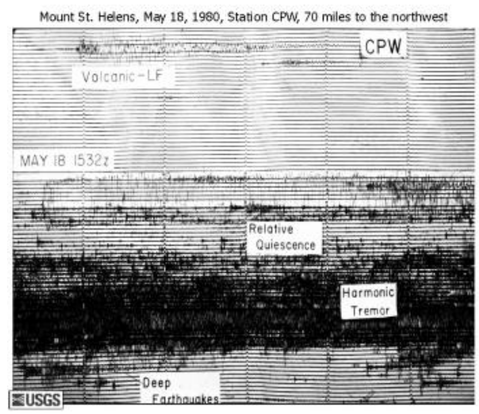
Washington Volcanoes

Glacier Peak
Mount Adams
Mount Baker
Mount Rainier
Mount St. Helens

Monitoring Seismicity to Locate Earthquakes

Earthquake activity is the most consistent sign of volcanic unrest.

Seismic networks, used to detect and locate earthquakes, have been a mainstay of Cascade volcano monitoring networks since the 1970s. Seismicity at Cascade volcanoes is monitored in partnership between the Pacific Northwest Seismic Network (PNSN) and the CVO, as well as UNAVCO (through the Plate Boundary Observatory program). There is significant variability in the number of stations at each volcano, which reflects the degree of difficulty in operating seismic stations in remote locations, proximity to population centers, recency of eruptive activity, and land-use permitting restrictions.



Seismogram from station CPW, 112 km (70 mi) northwest of Mount St. Helens, May 18, 1980

Learn more about volcano seismicity:

- The science behind volcanic seismicity and how it is analyzed is discussed at the Volcano Hazards Program website.
- Watch how scientists use earthquakes to detect magma movement on this volcano seismic monitoring video.

Seismic station at Three Sisters volcano in Central Oregon. Seismometer in box on the ground with data transmission antenna mounted on pole.

Seismic monitoring station SWFL—solar panels are used to recharge the batteries and keep the station running, Mount St. Helens.

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Deformation Monitoring Measures Inflation and Deflation of the Ground Surface

Deformation measurements herald rising magma.

At Cascade volcanoes, CVO scientists make measurements of land-surface movements using the Global Positioning System (GPS). More than 60 GPS stations continuously receive signals from satellites overhead and send the information to CVO, where it is analyzed to track the position of each station in three dimensions to within a small fraction of an inch. The GPS information allows CVO scientists to quickly detect any unusual movements that might occur as a result of magma accumulating beneath a volcano. In addition to continuously-operating GPS stations, CVO scientists conduct repeated temporary, campaign-style, GPS surveys to fill in areas where continuous monitoring is incomplete. They set up temporary GPS stations that receive satellite signals for a few days to months, and then analyze the resulting data together with that from continuously-operating stations. CVO scientists also use a remote-sensing technique called InSAR (interferometric synthetic aperture radar) to map subtle movements of the ground surface from space.

Tripod built in the 1980's serves as a modern GPS station at Studebaker Ridge, on the western flank of Mount St. Helens. View is to the north.

Learn more about the value of deformation studies:

Read about the several different ways that ground movement can be detected at the Volcano Hazards Program deformation monitoring webpages.

Monitoring enclosure at Newberry volcano, Oregon, with internal monitoring equipment, solar panels, and side-mounted antenna to transmit data.

Global Positioning System receiver (called a GPS monument) at North Rim Station, a monitoring location at Newberry volcano, Oregon.

Volcanic Gas Monitoring Gives Clues about Magma Below

Many Cascade volcanoes release gas continuously.

Volcanic gases provide the explosive power that drive volcanic eruptions. Monitoring the emission rates and chemical composition of volcanic gases can offer important clues to the inner workings of volcanoes. Gas emissions from the rugged Cascade volcanoes are sampled using airborne and ground-based techniques. In general, the gases emitted from Cascade volcanoes are from boiling hydrothermal fluids at depth and are rich in water vapor, carbon dioxide, and hydrogen sulfide. However, detailed chemical analyses show that the ultimate source of the heat and gases emitted from the major Cascade peaks is magma degassing at depth.

USGS geologist uses a UV spectrometer to detect gases from a fumerole at Crater Rock, Mount Hood, Oregon.

Learn more about volcanic gases.

- Read about the science behind volcanic gases and how to detect them at the Volcano Hazards Program website.
- Watch how scientists use earthquakes to detect magma movement in this volcano gas monitoring video.

Gas sample being collected into a glass vacuum flask using a titanium tube inserted into a fumarole from Sherman Crater, Mount Baker, Washington.

Gas sampling with a CO_2 Infrared Spectrometer at Mount St. Helens' September Lobe lava dome, Washington.

Automated Lahar Detection Systems

The Cascades Volcano Observatory uses Acoustic Flow Monitors (AFMs) to detect lahars originating on Cascades volcanoes. While typical seismometers will sometimes capture ground shaking, AFMs are designed to detect ground vibration at frequencies specifically associated with lahars, and are located in river valleys subject to frequent lahars. Data from an AFM station is radio telemetered to CVO, where computer processing allows for automated data screening and threshold exceedance notification. Currently, CVO operates a network of AFMs at Mount St. Helens, and cooperates with state and local agencies to maintain an AFM network at Mount Rainier. Additional AFM instruments can be deployed at other Cascades volcanoes when conditions warrant.

Learn more about monitoring lahars:

- General information about lahar detection systems and acoustic flow monitors.
- Mount Rainier lahar detection webpage.
- Hydrologic monitoring at Mount St. Helens.

Scientists maintain an Acoustic Flow Monitor (AMF) at Mount St. Helens, Washington. It detects ground movement associated with lahars.

Acoustic Flow Monitoring station can detect ground vibrations of a passing lahar or debris flow and provide early warning to people downstream. Station near Mount St. Helens, Washington.

Water Chemistry and Temperature Relate to Volcanic Activity

By monitoring the changes in chemistry and temperature of groundwater, surface water, and steam at a volcano over time, scientists can obtain useful information about changes in volcanic activity. These volcanic hydrothermal systems contain elemental components that signal the presence of magma, such as magmatic carbon dioxide or high helium-isotope ratios ($^3He/^4He$). Hydrothermal monitoring sites at Cascades volcanoes include instruments that measure water pressure (to calculate flow rate), temperature (to calculate quantities such as heat flow), and conductivity (to calculate concentrations of elements or chemicals). Scientists visit these sites regularly to take samples of liquid and gas and measure the rate of water flow. The results from these measurements indicate baseline conditions, help researchers determine whether hydrothermal activity is changing, and can indicate the presence or absence of fresh magma.

Streamflow measurement and water sampling at Paradise Creek are part of the regular measurements taken during hydrothermal monitoring campaigns at Mount Rainier, Washington.

For access to the hydrothermal data collected at Cascade Range volcanoes, visit the Hydrothermal Monitoring Data website.

Learn more about hydrothermal monitoring at Cascades volcanoes:

- Mount Rainier
- Mount Baker

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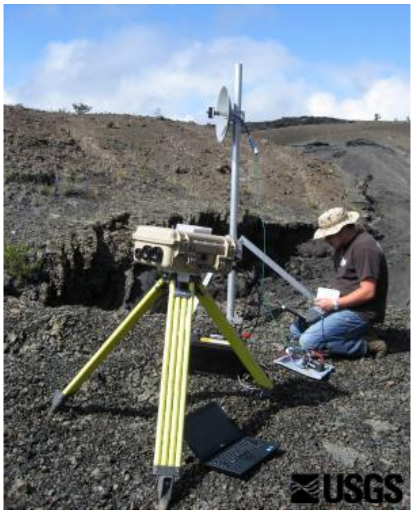
CVO Scientists Develop Innovative Tools for Improved Volcano Monitoring

Innovative monitoring and data transmittal increase eruption warning time.

Research and development scientists design, build, and test equipment for monitoring volcanoes in the U.S. and around the world. New instruments, software, and hardware developed by the USGS enable scientists to acquire, process, and interpret data quickly and effectively. Their work provides greater safety for field scientists, and increased warning time for officials and the public, thereby saving lives and property.



Camera captures SO2 released from Kilauea's summit vent

New tools support automated methods for measuring and transmitting volcano data.

Satellite technologies support careful measurements of ground deformation through InSAR. Ground-based RADAR can detect dense ash clouds in all-weather conditions. Thermal infrared cameras measure lava temperatures, and a new ultraviolet camera creates images of sulfur dioxide content in real time, allowing direct correlation with other geophysical data. Airborne and field geophysical monitoring can identify zones of weakened rock and wetted sub-surface that can indicate zones more susceptible to collapse. Scientists are improving earthquakes sensors' capability to detect sound waves (infrasound) that can record volcanic sound waves from tens to hundreds of miles away. The research and development group continues to convert seismic monitoring equipment from analog to digital format to increase the quality of the data and to accommodate the spectrum of radio frequencies available. New technologies allow for more rapid and reliable methods for data transmission from instruments on the volcano to CVO. A new telemetry system throughout the Cascade Range strengthens capabilities for reliable data transmission.

Spider instrument packages afford greater safety and efficiency.

A principal objective has been to adopt new technologies that integrate many instruments into a single package to lower power requirements, reduce instrument footprint on sensitive landscapes, be portable for rapid deployment into remote areas, and transmit data effectively back to the CVO. These requirements were met during the 2004-2008 eruption of Mount St. Helens when CVO engineers developed the Spider monitoring unit. The Spider houses several instruments in one container to detect earthquakes, ground swelling and contractions, as well as changes in gas chemistry from emitted volcanic fumes. The instrument spider can be deployed by helicopter, and reduces dangers to scientists who previously were required to spend long periods of time in hazardous volcanic areas. When volcano conditions are stable, scientists deploy permanent stations that use similar instrument packages for long-term volcano monitoring.

Deploying *spider* volcano-monitoring equipment in the crater of Mount St. Helens, Washington.