Capturing Mauna Loa’s Current Reawakening - Integrated Geodetic and Numerical Investigations of Magmatic and Volcanotectonic Processes, Mauna Loa, Hawaii

Benjamin A. Brooks » School of Ocean and Earth Science and Technology, University of Hawaii
James Foster » School of Ocean and Earth Science and Technology, University of Hawaii

Although its more recently active neighbor, Kilauea, has an extensive network of GPS stations, the coverage for Mauna Loa, Earth’s largest volcano, has been relatively sparse. In response to the onset of recent Mauna Loa reinflation, we have installed 11 additional continuous GPS (CGPS) receivers to provide denser coverage of the summit region and two flanking rift zones. This network should image future volcanic events on Mauna Loa and give new insights into structural and dynamic controls. Additionally, we have implemented a near real-time processing approach using the PAGES GPS software so that deformation events can be quickly identified for more detailed investigation. Preliminary solutions from this processing stream suggest that atmospheric heterogeneities present the most significant source of errors that must be assessed and mitigated in order to resolve the subtle or transient details of these events.

We analyze InSAR and GPS data collected over Mauna Loa’s summit and rift zones to explore recent magmatic-tectonic deformation of the volcano. The InSAR data include RADARSAT and ENVISAT images that together comprise 77 scenes and 149 interferograms from mid-1999 to mid-2006. The GPS data include periodic survey measurements and a network of continuous stations that has grown to more than 20 instruments over the past several years. In general, the InSAR and CGPS data agree well. Stacks of individual interferograms are dominated by large (cm scale) motions associated with recent (2002 to present) inflation of Mauna Loa’s summit region. Our results also detect a 9x15 km region of ~0.5 cm/yr line-of-sight lengthening (apparent subsidence) along Mauna Loa’s Southwest Rift Zone (SWRZ). The feature is present in all interferograms, including those that span time periods prior to the initiation of summit inflation. We explore hypotheses to explain this anomaly including: a) persistent atmospheric artifacts, b) deep-seated SWRZ opening, c) flank mobility related to SE-directed translation above a decollement, or d) a combination of deep-seated SWRZ opening and flank mobility, similar to the mechanism invoked to explain deformation of the south flank of neighboring Kilauea volcano. Although atmospheric water vapor anomalies are certainly very large in the region, the type of closed-contoured feature observed in the InSAR data is not reproduced by our analysis of high-resolution weather models from the region, and we are led to favor a volcano-tectonic explanation for the subsidence.

References

Figure 1. Continuous GPS data from Kilauea network. (A) Location map with study area shown by grey box. ML, Mauna Loa volcano; MK, Mauna Kea volcano; K, Kilauea volcano; HS, Hilina slump. SWRZ and ERZ are northward limits of the HS-bounding south-west and east Kilauea rift zones. White boxes are GPS stations shown in panels C-F. (B) Average yearly velocities (grey arrows) from GPS stations (red text) for 1997-2005, ellipses indicate 2σ errors. White dots are seismicity from the HVO catalog archived at the Northern California Earthquake Data Center for the same time period. Only those earthquakes occurring in the HS volume and at depths less than 20km are shown. Inverted white triangle is the rain gauge site at National Park service headquarters. (C) HP indicates the position of the Hilina Pali scarp. (F); 9 Nov. 2000 (D); 16 Dec. 2002 (E); and 26 Jan. 2005 (F). B.A. Brooks et al. / Earth and Planetary Science Letters 246 (2006) 207-216.

3-80
Accelerated Uplift of the Yellowstone Caldera, 2004-2006, from GPS and InSAR Observations

Wu-Lung Chang » Department of Geology and Geophysics, University of Utah
Robert B. Smith » Department of Geology and Geophysics, University of Utah
Christine M. Puskas » Department of Geology and Geophysics, University of Utah
Jamie J. Farrell » Department of Geology and Geophysics, University of Utah
Chuck Wicks » U.S. Geological Survey, Menlo Park, CA

Geodetic techniques have been employed to monitor the crustal motion of Yellowstone beginning with the precise leveling of benchmarks installed in 1923. Since 1997, the University of Utah has installed six permanent GPS stations inside Yellowstone National Park for continuously monitoring the ground deformation associated with seismic, volcanic, and hydrothermal activities. Starting in mid-2004, the GPS network recorded an episode of unprecedented uplift of the Yellowstone caldera concomitant with subsidence of the northeast caldera area including Norris Geyser Basin. The deformation continues into 2007, with nearly constant inflation rates of ~6 cm/yr and 4 cm/yr at the Sour Creek and Mallard Lake resurgent domes, respectively (Figure 1). These rates are up to three times faster than preceding caldera uplift rate from 1923 and 1984. The horizontal velocities, in addition, are 7 to 21 mm/yr outward from both domes. Meanwhile, Norris Geyser Basin experienced subsidence at ~4 cm/yr that is two times higher than the 1996-2002 uplift rate. Incorporating GPS data from the University of Utah and five new PBO stations, we evaluated source models by inverting the GPS and InSAR data for the geometry and expansion (contraction) of dislocations in an elastic half-space [Chang et al., 2007]. The results indicate two horizontal sill-like structures ~8 km beneath the caldera with a total volumetric expansion rate of 0.11 km$^3$/yr, and a northwest-dipping tabular body 16 km beneath the Norris Geyser Basin with a volumetric contraction rate of 0.018 km$^3$/yr. Incorporating seismic, hydrothermal, and geochemical evidence, we propose that a new intrusion of magma into the mid-crustal or pressurization of a deep hydrothermal system likely caused the uplift within the Yellowstone caldera. The Norris subsidence, in contrast, may be induced by the crystallization and contraction of crustal magmatic bodies and the associated loss of dissolved fluid and gas to shallow fault and hydrothermal systems.

Figure 1. (a) Locations of measured uplift in the Yellowstone caldera. (b) Time series of vertical motion measured at six sites.

References

This research was supported by NSF Grants #0314298, #9725431, and #9316289.
Accuracy Assessment of High-rate GPS for Detection of Short-Term Motions

P. Elosegui » Institute for Space Sciences, CSIC-IEEC, Barcelona, Spain
J. L. Davis » Harvard-Smithsonian Center for Astrophysics, Cambridge, MA

We adopted an instrumental approach to assess the accuracy of high-rate GPS to detect transient, short-term (seconds to days) surface motions, such as those associated with glacial flow, surges, glacial earthquakes, active volcanoes, and in particular the seismic motions associated with earthquakes. We built an apparatus for translating a GPS antenna on a positioning table that is accurate to better than 0.1 mm in position, and thus provides the “ground truth” displacements for assessing the technique of high-sample-rate (~1 Hz) GPS. The GPS antenna attached to this positioning table undergoes simulated (seismic or other) motions of the Earth’s surface while collecting high-rate GPS data. Analysis of the time-dependent position estimates can then be compared to the ground truth, and the resultant GPS error spectrum can be measured. In Elosegui et al. [2006], we reported that millimeter-level accuracy can be achieved for GPS position determinations in high-sample-rate applications (Figure 1).

This work is an extension of Elosegui et al. [1996], in which we translated a GPS antenna in the horizontal plane at 1 mm/hr for more than 24 hours. By modeling the time-dependent position as a random walk and fitting a straight line to the stochastic estimates, they showed that the accuracy of the velocity estimates was dependent on the observing period and the baseline lengths. For example, for 24-hour data time spans, the root-mean-square (rms) horizontal and vertical velocity errors were less than 0.2 and 0.9 mm/hr, respectively, for baselines between 10 m and ~1000 km.

References

This work was supported by NASA, the Smithsonian Institution, and the Spanish Ministry of Education and Science.

Figure 1. Results from ground-truth studies of the accuracy of the GPS-seismology technique of Elosegui et al. [2006]. A GPS antenna was installed on a high-accuracy positioning table, which was then used to simulate the motions of an earthquake. The programmed motion is shown in the figure by the blue line. The GPS data acquired during the simulated earthquake were analyzed to provide time-dependent determinations of site position, shown by the red dots. The error in the position estimate (green curve) over the 15-min span of the simulated earthquake has a maximum value of 10 mm and an rms value of 2.5 mm.
Augustine Volcano: PBO Data

Jeff Freymueller » Geophysical Institute, University of Alaska Fairbanks

PBO data recorded before and during the eruption of Augustine Volcano provided new insights into the magmatic plumbing system at Augustine volcano, as well as surprises that will require further research to understand. These results give an example of the future gains expected from measuring deformation at other PBO volcanoes.

The first sign of unrest at Augustine appeared in early summer 2005, with an increase in seismicity accompanied by a small inflation signal. Surprisingly, from the beginning the inflation signal indicated a source at shallow depth, roughly at sea level. Campaign GPS measurements over the 15 years prior to the eruption indicated no previous accumulation of magma at such shallow depth. The initial inflation source was small, detectable only by high-quality continuous GPS, and it may be that deformation associated with the rise of this small initial pod of magma was simply too small to record with GPS – strainmeters or tiltmeters such as those that PBO plans to install might have provided further important data about the initial rise of magma.

Once significant extrusion of magma began, about two weeks after the first major explosions, the surviving PBO sites recorded a deflation signal with a different spatial pattern than the inflation. Although only weakly constrained by PBO data because two sites were destroyed quickly, the deflation source clearly came from a significantly greater depth than the inflation source. Additional data from temporary sites deployed just before the volcano became too dangerous to visit helped constrain the source depth to mid-crustal depths. Together with the lack of pre-eruptive deformation prior to 2005, these observations lead to a model for the magma rise in which small leading pods ascended from mid-crustal depths, eventually reaching the surface. After there was a continuous magma column from the surface to mid-crustal depths, sustained extrusion began.

The destruction of some sites in the initial explosions and the first major pyroclastic flow also illustrated the need for redundancy in network design. Additional instrumentation installed on Augustine since the eruption addresses that need. The value of additional temporary continuous sites also suggests a future use for part of the PBO campaign instrument pool, as long as funding and approval for rapid response can be obtained.

References

Monitoring the Augustine Volcano

Jeff Freymueller » Geophysical Institute, University of Alaska Fairbanks
Peter Cervelli » U.S. Geological Survey, Alaska Volcano Observatory

After months of increasing unrest and precursory deformation, Augustine volcano began to experience small explosions in mid-December 2005. Although there were five Plate Boundary Observatory (PBO) continuous GPS sites on the island, the PBO network was concentrated near the summit and upper flanks of the volcano. These locations made the network very sensitive to shallow deformation source, but the lack of stations farther from the summit limited the resolution of deeper source. In December, Alaska Volcano Observatory made the decision to install several temporary continuous sites on the island. We were constrained by winter weather and lack of daylight, and by safety concerns, so a full-blown PBO-style installation was impossible. We sought an alternative that would allow a quick installation, and found the answer in the UNAVCO web pages. We borrowed Tech-2000 antenna masts from UNAVCO (Figure 1), and had our machine shop make up additional simplified antenna masts based on the same design. These antenna masts allowed a complete site to be set up in about an hour, and we set up 5 sites around the lower flanks of the volcano, recording locally and using only battery power. A sixth planned site could not be installed due to bad weather. Moving quickly was critical—soon after our installations it became too unsafe to work on the island. At the three sites where bedrock was available to anchor the chains, the masts were stable over a period of several months, and provided useful data constraining the deeper deflationary source observed in the eruption.

Figure 1. University of Alaska Fairbanks student Tom Fournier sets up a temporary continuous site on the south flank of Augustine volcano, using a borrowed UNAVCO Tech-2000 mast.

Figure 2. Site AUGB on the north coast of Augustine Island moved abruptly to the south during the eruption, around 2006.1. Data from this and other sites are consistent with a deep (mid-crustal) deflation source.
Space geodetic methods combined with imaging are used to inspect active tectonics and magmatism within the Macolod Corridor and the Taal Caldera, a geologically complex area in Southwestern Luzon. This area is characterized by extensive volcanism and widespread faulting. Radar and multispectral imageries subjected through analytical shading and image filtering techniques and combined with digital terrain models are used to analyze fault orientations and detailed geomorphic features of the area. Campaign geodetic observations (1996-2002) from GPS stations within Luzon are used in combination with remote sensing and earthquake slip vectors to derive the kinematics of Luzon. We use an elastic block modeling approach, which characterizes crustal deformation as a result of rotation of discrete elastic microplates around Euler poles. The resulting best-fit model indicates that the Luzon area is composed of six microplates. The vicinity Macolod area in SW Luzon is best represented with three mobile microplates. Active tectonics of the Philippine mobile belt is dominated by eastward subduction along the Manila Trench (~20 to 100 mm y⁻¹), westward subduction along the Philippine Trench (~29 to 34 mm y⁻¹), and sinistral strike-slip faulting along the Philippine Fault (~10 to 40 mm y⁻¹). The velocity field indicates localized transpression along the N-S trending Marikina Fault (~10 to 12 mm y⁻¹), and transtensional motion along the NE-SW trending Macolod Corridor fault zone (~5 to 10 mm y⁻¹) (Galgana, 2005). Observations from the continuous single- and dual-frequency GPS stations of the Taal Volcano network from 1998-2005 indicate a sequence of inflationary and deflationary events, which include several periods of rapid volcanic inflation (~120 mm uplift from February to November 2000) and rapid deflation (~33 mm subsidence from June to December 1999). The most recent episode of inflation extended from June 2004 to March 2005 indicated ~73 mm y⁻¹ extension across the volcanic edifice, with about 50 mm uplift with respect to the caldera wall. A recent deflationary pattern starting April 2005 is also detected. Models for the earlier inflation and deflation events indicate that a Mogi point source 4 to 5 km deep centered at the Volcano Island describes the deformation effectively. The inflationary trends are interpreted to be episodes of magma intrusion to a shallow reservoir beneath Volcano Island, which is significantly affected by regional tectonism (Bartel, 2002).
Magma Movement at Galápagos Shield Volcanoes

Dennis Geist » University of Idaho
William Chadwick » Oregon State University/NOAA, Newport
Charles Meertens » UNAVCO, Boulder, CO
Beth Bartel » UNAVCO, Boulder, CO

Campaign GPS measurements at Fernandina and Sierra Negra calderas from 2000-2002 revealed extraordinary extents of deformation of the caldera floors and flanks of the volcanoes, undoubtedly due to the intrusion of magma into shallow reservoirs between eruptions (Geist et al., 2006). Regular expansion of Fernandina is modeled as pressurization of a subcaldera sill that lies about 2 km beneath the caldera floor. This inflation culminated in an eruption in May 2005. We reoccupied the Fernandina network in June 2005 and found that the eruptive fissure serendipitously intruded directly between 2 benchmarks only 500 m apart; those data are currently being processed.

Sierra Negra displayed more complicated behavior before its latest eruption, which began on 22 October 2005. From 2001-2002, the caldera floor subsided, although there was no eruption. From 2002 onward, the deformation of the volcano has been captured in great detail by a six-station continuous GPS network. Subsidence continued until 2003, when the caldera floor began uplifting. The caldera floor then inflated at accelerating rates up until the time of the eruption. The results of this geodetic monitoring show that the filling and pressurization of an ~2-km-deep sill eventually led to an eruption that began on 22 October 2005. The continuous GPS monitoring measured >2 m of accelerating inflation leading up to the eruption and contributed to nearly 5 m of total uplift since 1992, the largest precursory inflation ever recorded at a basaltic caldera. This extraordinary uplift was accommodated in part by repeated trapdoor faulting, and coseismic GPS data provide strong constraints for improved deformation models. These results highlight the feedbacks between inflation, faulting, and eruption at a basaltic volcano, and demonstrate that faulting above an intruding magma body can relieve accumulated strain and effectively postpone eruption.

Figure 1. Continuous global positioning system (CGPS) results showing pre-eruption deformation at Sierra Negra volcano. A: Location map after Yun et al. (2006). B: Summit of Sierra Negra, showing sinuous ridge fault system, location of CGPS stations, and horizontal displacements during inflation from 1 April 2003 to 21 October 2005 (GV01 only to 3 December 2004; GV02 only to 10 June 2005). Fault-related displacements on 16 April 2005 are not included (see Figure 2). C: Vertical displacements during inflation, as in B. D: Uplift history of the center of the caldera at Sierra Negra from 1992 to 2006 amounting to nearly 5 m. Times of major trapdoor faulting events and 2005 eruption are indicated. E: Horizontal displacements (north component only) at CGPS stations from 2002 to 2006, relative to stations GALA and GLPS on Isla Santa Cruz. Noise level increases after 10 June 2005, when both dual frequency receivers had failed (GV01 and GV02). Afer 1 September 2005, GALA and GLPS were also down; thereafter movement at GV03 is extrapolated (dashed line) and GV04, GV05, and GV06 are shown relative to GV03. F: Vertical displacement time series, as in E. Inset shows kinematic solution for displacements at GV06 during 16 April 2005 trapdoor faulting event, relative to GV03. Vertical dashed lines in E and F show times of 16 April 2005 trapdoor faulting event and eruption on 22 October 2005. InSAR—inferometric synthetic aperture radar; GPS—global positioning system.

The collaborative work with UNAVCO has been supported by NSF grants EAR-0004067 and EAR-0538205.

References


Chadwick, WW, Geist, D., Jonsson, S, Poland, M, Johnson, D and Meertens, C, Volcano bursting at the seams: Inflation, faulting, and eruption at Sierra Negra volcano, Galapagos, Geology, in press, 2006.
Magmatic Systems

Recent Seismicity and Surface Deformation at Lake Tahoe: An Update on Lower Crustal Magma Movement

William C. Hammond » Nevada Bureau of Mines and Geology, University of Nevada
Geoff Blewitt » Nevada Bureau of Mines and Geology, University of Nevada
Corne Kreemer » Nevada Bureau of Mines and Geology, University of Nevada
Hans-Peter Plag » Nevada Bureau of Mines and Geology, University of Nevada
John Anderson » Nevada Seismological Laboratory, University of Nevada
Ken Smith » Nevada Seismological Laboratory, University of Nevada

In late 2003 a lower crustal seismic swarm (29-33 km depth) occurred beneath the north end of Lake Tahoe on the California-Nevada border. This swarm was accompanied by an ~1 cm northeastward motion of the continuous GPS site SLID on Slide Mountain, Nevada. The position and motion of SLID with respect to the northeast-dipping planar cluster of seismicity suggested that the earthquakes and surface motion were caused by a progressive filling of a crack with magma, injected from below [Blewitt, 2004; Smith et al., 2004]. This activity began again in mid-2005 when another movement, of size and direction nearly equal to the 2003 event, was observed with GPS at SLID. However, this time the associated cluster of seismic activity was shallower and more energetic (Figure 1). The distribution of shallow seismicity follows a spatial pattern that is strongly focused to the north of the original swarm, and divided into separate northwest and northeast trending clusters. This distribution suggests some influence by the tectonic structures of the Great Basin/Sierra Nevada transition zone, and may provide some clues about the state of stress in this active transtensional system. We have established nine new GPS sites around the Tahoe region that will help constrain the depth and location of future fluid motions should they occur [Hammond et al., 2006]. Planned installations for PBO will further enhance our ability to monitor this motion.

References
Geodetic GPS Measurements in South Iceland

P.C. LaFemina » Department of Geosciences, Penn State University
T.H. Dixon » Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
R. Malservisi » Ludwig-Maximilian University, Munich, Germany
T. Árnadóttir » Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland
E. Sturkell » Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland
F. Sigmundsson » Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Reykjavik, Iceland
P. Einarsson » Science Institute, University of Iceland, Reykjavik, Iceland

GPS observations in south Iceland between 1994 and 2003 are compared with two-dimensional elastic half space and viscoelastic coupling models for two parallel rift zones, representing the Western and Eastern Volcanic Zones (WVZ, EVZ). GPS data from the Hreppar block, between the WVZ and EVZ, fit a rigid block model within the uncertainties. Spreading rates across the WVZ increase from 2.6 ± 0.9 mm/yr in the northeast to 7.0 ± 0.4 mm/yr in the southwest. Conversely, spreading rates in the EVZ decrease from 19.0 ± 2.0 mm/yr in the northeast to 11.0 ± 0.8 mm/yr in the southwest, the direction of ridge propagation. Summed extension rates across the two rift zones are approximately constant and equal to the total plate rate, ~18 to 20 mm/yr, consistent with a simple propagating ridge model whereby the WVZ is deactivating in the direction of EVZ propagation. The coupling model confirms results from the simple elastic half space model, including relatively shallow locking depths (< 5 km) beneath the rift zones, and allows for an estimate of mean viscosity (~10^{19} to 10^{20} Pa s) beneath the elastic layer. The location of maximum surface velocity gradient in the EVZ, presumably the locus of sub-surface magma accumulation and future rifting, does not coincide with the 1783-84 Lakagígar fissure eruption, but is 20 km to the west on the Bárðabunga-Veidivötn fissure swarm. This site had a small volume eruption in 1862-64, and a major eruption in 1477 AD.

We are continuing this research with additional EGPS observations and the installation of continuous GPS (CGPS) and semi-CGPS across the EVZ as part of the Hekla CGPS network.

Reference
High Rate CGPS Instrumentation on Cotopaxi Volcano

P. LaFemina » Department of Geosciences, Penn State University
P. Mothes » Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador
T. Dixon » Rosenstiel School of Marine and Atmospheric Sciences, University of Miami
C. Connor » Dept of Geology, University of South Florida
D. Rivero » Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador
C. Ramos » Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador
L. Troncoso » Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador
W. Enríquez » Instituto Geofísico, Escuela Politécnica Nacional, Quito, Ecuador

Cotopaxi volcano, Ecuador, is a large stratovolcano located approximately 60 km south of the capitol city Quito. The last important eruption (VEI 4) occurred in 1877 and mild eruptive activity continued into the early 1900s. In an effort to improve the deformation monitoring of Cotopaxi volcano, two dual frequency (L1/L2) GPS receivers (Trimble NetRS receivers with Zephyr Geodetic antennas with ground planes) were installed in early 2005 on the NE and SW flanks of Cotopaxi at 4400 m elevation, with a baseline length of approximately 8 km. Data arrives to the Instituto Geofísico-Quito in real time via telemetry/ethernet connection. Data processing will assess probable correlations between the vigorous seismic swarms and increased gas exhalations from the crater, which are observed by a permanent video camera on the crater rim (5890 m), with possible inflationary/deflationary cycles related to the migration of magma and/or magmatic volatiles. This new instrumentation compliments the data obtained from two L1 GPS instruments operating since 2002 (installed by UNAVCO), six EDM arrays measured since 1987, and two telemetered tiltmeters.

Figure 1. Photograph of CGPS site CONE on the northeast flank of Cotopaxi volcano. This CGPS site along with CGPS site MORU span the edifice with a baseline length of 8 km. The CONE monument is 0.5 m spike mount, epoxied into a glaciated lava flow.
We have installed six (6) CGPS stations at Hekla volcano, Iceland, to improve the monitoring and understanding of this plate boundary volcano. This network is imbedded within an episodic GPS network at Hekla volcano and Torfajokull volcano. The Hekla volcano has been measured since 1996 and the Torfajokull volcano since 2000. Hekla volcano is located at the intersection of the South Iceland Seismic Zone (SISZ) and the eastern volcanic zone (EVZ) and has erupted seven times in the last century, including four eruptions in the last 34 years. The trend of the volcano is oblique to the spreading direction, and therefore may be influenced by strain accumulation across the SISZ and EVZ. To better understand deformation of the volcano, we must understand the background tectonic signal including uplift (e.g., LaFemina et al., 2005).

Monitoring volcano deformation with 1-Hz CGPS allows us to investigate the dynamic and static processes that occur within and around a volcanic edifice during periods of eruptive activity and quiescence (e.g., Mattia et al., 2004). This monitoring leads to the potential for detecting precursory activity, including magma migration through the edifice, and the prediction/forecasting of a volcanic eruption. During quiescent periods CGPS data allows for investigation of a volcano’s magma-tectonic context at a more regional scale. This network also allows for testing of telemetry and power systems in extreme environments.

References


Deformation Associated with Eruptive Activity at Mount St. Helens, Washington

Michael Lisowski » U.S. Geological Survey, Cascades Volcano Observatory
Larry Mastin » U.S. Geological Survey, Cascades Volcano Observatory
Daniel Dzurisin » U.S. Geological Survey, Cascades Volcano Observatory
Michael Poland » U.S. Geological Survey, Hawaiian Volcano Observatory

On September 23, 2004, a seismic swarm marked the onset of eruptive activity at Mount St. Helens, Washington, after 18 years of quiescence. A few days later, an intensely deforming, uplifted welt was recognized in the southeast part of the crater, and a series of phreatic explosions lasting five days began on October 1, 2004. The USGS Cascades Volcano Observatory and Plate Boundary Observatory responded by deploying 18 continuous GPS stations on and around the flanks of the volcano, in addition to other stations elsewhere in the region. The network has measured remarkably little deformation. Prior to the eruption, only one continuous GPS station, JRO1, was operating, 8 km north of the volcano. JRO1 recorded about 2 cm of displacement towards the volcano during the first two weeks of the unrest. Between mid-October 2004 and the end of 2005, the GPS network detected only a few cm of deflation of the volcano. Deformation from Interferometric Synthetic Aperture Radar (InSAR) is similarly muted; a stack of 9 RADARSAT interferograms spanning 2004-2005 shows only about 2 cm of line-of-sight deflation centered on Mount St. Helens.

Deformation from InSAR and GPS can be approximated by a volume loss of 20-30 × 10⁶ m³/yr at depths of 6 to 12 km (depending on the model geometry). Interestingly, during this time period at least 70 × 10⁶ m³/yr of lava was extruded. This discrepancy in volume does not necessarily imply recharge to the magma reservoir at depth. The difference can also be explained by the expansion of bubbles in the reservoir as volume is removed. Continued geodetic research at Mount St. Helens offers the chance to further investigate a variety of important issues in volcanology, including the relationship between erupted volume and modeled volume loss, the geometry and size of the magma reservoir, and the relationship between deformation rates and eruptive activity (e.g., explosive activity, effusion rate, magma chemistry, etc.).

Figure 1. InSAR results from Mount St. Helens showing (A) observed, (B) modeled, and (C) residual deformation. Observed line-of-sight displacements are from a stack of 9 RADARSAT standard model 2 interferograms spanning 2004-2005. The model assumes a point source at 12 km depth with a volume loss of 27 × 10⁶ m³/yr.

Figure 2. Top: Average observed (black) and modeled (red) GPS displacements from Mount St. Helens between October 15, 2004 and December 31, 2005. The model assumes a vertical prolate ellipsoid between 6 and 12 km depth beneath the volcano with a volume loss of 20 × 10⁶ m³/yr. Bottom: Time series of displacements from continuous GPS stations on the flanks of Mount St. Helens. Red line marks the onset of seismic unrest on September 23 2004.
Transient episodes of ground displacement related to the dynamics of magmatic fluids as possible precursors to eruptive activity can be revealed through a careful analysis of high rate GPS (HRGPS) data. In the very first phases of an eruption the real time processing of high rate GPS data can be used by civil protection authorities to monitor the opening of fractures fields on the slopes of volcanoes. During eruption, large explosions, opening of vents, migration of fractures fields, landslides and other dangerous phenomena can be monitored and their potential for damage estimated. This technique has already revealed its importance during the 2002-2003 Stromboli Island (Italy) eruption (Mattia et al., 2004).

In order to improve our ability to fully explore the HRGPS signal in volcanic areas, we have developed new software tools for analysis in both time and frequency domains. We have been able to characterize typical peaks of frequencies related to 1) sidereal effects attributed to the position of satellites (Bock et al., 2000), 2) thermoelastic effects on the pillars of GPS stations, and 3) earth tide effects. These “noise” sources can be filtered in order to improve the measurement accuracy and can be implemented in a real-time system. Furthermore, our analysis has revealed characteristics of the HRGPS signal that may indicate a possible precursor of renewed volcanic activity. We have applied this approach to data collected during the recent eruptions of Stromboli (Italy), Etna (Italy) and Augustine (Alaska, USA) volcanoes.

References:


This work was (partially) funded by the Italian Dipartimento della Protezione Civile in the frame of the 2004-2006 agreement with Istituto Nazionale di Geofisica e Vulcanologia – INGV. We thank the PBO project and UNAVCO for the GPS data.
The CALIPSO Project at Soufrière Hills Volcano, Montserrat, BWI: Using Integrated Deformation Data to Constrain Magmatic Processes

Glen Mattioli » Department of Geosciences, University of Arkansas
Barry Voight » Department of Geosciences, Penn State University
Derek Elsworth » Department of Geosciences, Penn State University
Dannie Hidayat » Department of Geosciences, Penn State University
Alan Linde » Department of Terrestrial Magnetism, Carnegie Institution of Washington, DC
Peter Malin » Division of Earth Sciences, Duke University
Jurgen Nueberg » School of the Earth and Environment, University of Leeds, Leeds, UK
Selwyn Sacks » Department of Terrestrial Magnetism, Carnegie Institution of Washington, DC
Eylon Shalev » Division of Earth Sciences, Duke University
Steve Sparks » Department of Earth Sciences, University of Bristol, Bristol, UK
The staff of the MVO » Montserrat Volcano Observatory, Flemmings, Montserrat, British West Indies

The “Caribbean Andesite Lava Island Precision Seismo-geodetic Observatory,” (i.e. CALIPSO) has greatly enhanced the geophysical infrastructure at the Soufrière Hills Volcano (SHV), Montserrat with installation of an integrated array of borehole and surface instrumentation at four sites. Each site has a Sacks-Evertson dilatometer, a three-component seismometer (~Hz to 1 kHz), a Pinnacle Technologies tiltmeter, and an Ashtech u-Z CGPS receiver with choke ring antenna, similar to volcano sites in western North America as part of EarthScope. CALIPSO sensors recorded the collapse of the SHV lava dome on Montserrat in July 2003, the largest such event worldwide in the historical record (Mattioli et al., 2004). Dilatometer data show remarkable and unprecedented rapid (~600s) pressurization of a deep source. Voight et al. (2006) inferred an oblate spheroidal source with average radius ~1 km centered at 5.5 to 6 km depth. An overpressure of ~1 MPa was attributed to growth of 1 to 3% of gas bubbles in supersaturated magma, triggered by the dynamics of dome unloading.

Pyroclastic flows entering the sea may cause tsunami generation at coastal volcanoes worldwide, but geophysically monitored field occurrences are very rare. Mattioli et al. (2007) reconstructed the process of tsunami generation and propagation during the prolonged, gigantic collapse of the SHV in 2003 using a combination of data from the CALIPSO array. Mattioli (2005) also reported that periods of surface uplift recorded by GPS at SHV correspond to an inflating, while subsidence corresponds to a deflating Mogi source. Inverted depths are between 6 and 13 km, with the recent observations favoring a deeper source. These measurements support a temporal evolution of the mid-crustal pre-eruption storage zone from 1995 to 2005.

References
Mattioli, G.S., 2005, CALIPSO, and a decade of GPS surface deformation: what we have learned from Soufrière Hills volcano (Invited), Montserrat, Proc. of “Soufrière Hills Volcano – Ten Years On.” Seismic Research Unit, Univ. West Indies Press, in press.

This work was supported by NSF-EAR Awards 0116485, 0507334, 0523097, and 0607782 to UARK.
Magmatic Deformation in Hawaii

Asta Miklius » U.S. Geological Survey, Hawaiian Volcano Observatory
Michael Poland » U.S. Geological Survey, Hawaiian Volcano Observatory

The past five years have brought an unprecedented variety of deformation at Mauna Loa and Kilauea volcanoes in Hawaii. This deformation was well characterized by a GPS network installed and operated collaboratively by the USGS, University of Hawaii, and Stanford University (Miklius et al., 2005). For the vast majority of the 1983-present eruption, deflation has occurred at Kilauea’s summit. Starting in 2000, the subsidence slowed and gradually turned to uplift, apparently related to an increase in magma supply to the shallow volcanic system. The uplift rate has varied over time, which rapid inflation marking the end of 2005. In addition, there have been several aseismic fault slip events on the south flank of the volcano between 1998 and 2005. Publications documenting the “slow earthquakes” include Cervelli et al. (2002), Brooks et al. (2006) and Segall et al. (2006).

Mauna Loa had been deflating since 1994 but abruptly began inflating in May 2002, at the same time as a surge in lava effusion from the Puʻu ʻOʻo vent on Kilauea volcano. The presence of continuous GPS networks on both volcanoes allowed such amazing behavior to be recognized. Miklius and Cervelli (2003) speculated that a pulse of magma introduced into Mauna Loa’s plumbing system affected Kilauea’s already pressurized shallow magma system, providing the stress necessary to trigger the effusive episode. Inflation of Mauna Loa has continued to the present, and was punctuated by a five-fold increase in rate between mid-2004 and mid-2005. The deformation can be modeled as volume increase in a point source located beneath Mauna Loa’s southeast caldera rim and in a dike-like body aligned SW-NE beneath the caldera.

References


Figure 1. Average horizontal displacement rates form 2002 through 2004 on the Island of Hawaii. The velocity of the continuous site on Mauna Kea (just off the top of the figure) has been removed to correct for Pacific plate motion. Major signals include inflation of Mauna Loa volcano and seaward motion of Kilauea’s south flank.

Figure 2. Time series of line-length change across Kilauea caldera (left) and Mauna Loa’s caldera (right). Extension is positive, with increases in line-length indicating volcano inflation. Insets show station locations on the volcano.
Reoccupation of the Riobamba (RIOP) Monument, Ecuador

P. Mothes » Instituto Geofísico, Escuela Politécnica Nacional, Quito Ecuador
P. LaFemina » Department of Geosciences, Penn State University
D. Rivero » Instituto Geofísico, Escuela Politécnica Nacional, Quito Ecuador
C. Ramos » Instituto Geofísico, Escuela Politécnica Nacional, Quito Ecuador
J. Pozo » Instituto Geofísico, Escuela Politécnica Nacional, Quito Ecuador
D. Cisneros » Dept de Geodesia, Instituto Geográfico Militar, Quito, Ecuador

The Riobamba (RIOP) site was established during the CASA project in 1996 and operated from 1996 to 2001, functioning as a permanent station, hosting a Rogue SNR-8000 receiver and a TuboRogue Dorn Margolin with chokering antenna. Its cement monument is located on a military base in Riobamba, Ecuador. Data were sent via a fixed modem/phone line to a computer at the Instituto Geográfico Militar in Quito, and then transferred via FTP to UNAVCO. About 500 days of data are shared at the UNAVCO facility.

Since early January 2007, the station has been operating on a permanent basis. Instrumentation includes a Trimble SSI receiver and a Trimble chokering antenna. Data access via modem/phone line is being arranged; however at the moment the data are being downloaded every two weeks and are being temporarily stored at the Instituto Geofísico, before transferal to UNAVCO. The data will be used to help constrain deformation patterns on the nearby erupting Tungurahua volcano and also serve as a control point in the InterAndean Valley to determine local and regional deformation.

Figure 1: Reoccupation of the RIOP monument in Riobamba, Ecuador. The station had been abandoned for six years.
Santorini Caldera in the southern Aegean is part of a well developed but still very active volcanic system fueled by subduction along the Hellenic arc. The caldera is partially submerged, with only pieces of caldera wall, flanks and central post-caldera lavas exposed above the sea level, composing a group of five small islands. The system had its most recent caldera-forming event around 1650 B.C. in a massive series of Pliocene eruptions that expelled some 60 km$^3$ of volcanic material [Sírđudsson et al., 2006], burying the previous island surface, and possibly contributing to the demise of the Minoan civilization. Additionally, the eruption likely caused widespread and locally large tsunami waves across the Aegean and Mediterranean Seas. The system remains active with ongoing smaller pyroclastic and phreatic eruptions, the most recent in the 1950s, forming the central islets atop of the submerged caldera floor.

In late-spring 2006, with UNAVCO engineering support, we established a network of two continuous GPS across the caldera, and will soon finish a third site atop one of the young central islets. As well, we performed a first GPS campaign of 18 previously established and new sites across the five-island group. Currently, we are planning a second set of measurements for spring-summer 2007. Through the continuous and campaign measurements we hope to establish the rate of ongoing deformation and determine if there exists any significant transient deformation that would yield valuable information about near source rheology and pressure history. This information may additionally be useful for understanding the early post-caldera resurgence in a mostly submerged environment. As well, this information may be useful for early hazard awareness and mitigation during future regional volcanic crises.

References


This work was supported by Georgia Institute of Technology, College of Sciences.
Ongoing Transient Deformation from a Shallow Socorro Magma Body?

Andrew V. Newman » Earth and Atmospheric Sciences, Georgia Institute of Technology  
Dave Love » New Mexico Bureau of Geology and Mineral Resources  
Richard Chamberlain » New Mexico Bureau of Geology and Mineral Resources  
Timothy H. Dixon » Marine Geology and Geophysics-RSMAS, University of Miami  
Peter LaFemina » Marine Geology and Geophysics-RSMAS, University of Miami  
Susan L. Bilek » Earth and Environmental Sciences, New Mexico Tech  
Richard Aster » Earth and Environmental Sciences, New Mexico Tech

The Socorro Magma Body (SMB), between Socorro and Belen, New Mexico, lies within the central portion of the Rio Grande Rift Valley and is one of the largest known magma bodies in Earth's continental crust. The SMB is expressed in several geophysical anomalies, including increased local seismicity, low electric conductivity, and surface uplift. Studies of local microseismicity and deep seismic soundings revealed an unusual crustal reflector about 50 to 70 km wide, and about 19 km in depth, and were interpreted as requiring fluids, most likely melt, in the middle crust beneath Socorro. These data have led to a general acceptance of the Socorro reflector as the prime example of a large active sill-like magma intrusion. Using precision leveling and Interferometric Synthetic Aperture Radar, previous studies have found averaged uplift of about 2 to 4 mm/yr centered on the Socorro seismic reflector at 19 km depth.

We performed three GPS campaigns over 9 to 12 bedrock sites in 2002, 2003, and 2005. Vertical GPS over the southern SMB switch from between +10 and 20 mm with the maximum uplift (20 mm) in 2002, to a similar level deflation the following year. Currently, these data suggest a significant and smaller body transiently inflating at about 5km depth and corresponding to 0.5-5 million m³ between 2002 and 2003. These results indicate that the SMB may have considerable variation in the spatio-temporal pattern of deformation averaging to a slower long-term inflation.

In fall of 2005, with the help of UNAVCO field engineers, we installed two new continuous GPS sites near the center of transient inflation. In collaboration with Los Alamos National Laboratory and New Mexico Tech, these sites are collocated with two continuously recording broadband seismometers aimed at identifying low-frequency tremors associated with migrating fluids.

References:


The work was supported by LANL-NMT MOU Grant; Georgia Tech, College of Sciences.
Long Valley Caldera is situated in east-central California on the eastern edge of the Sierra Nevada range and is a major volcanic focus site for the ongoing NSF-EarthScope Project. The 20 × 30 km² caldera was created ~760,000 years ago in a large ignimbrite eruption. This eruption expelled more than 600 km³ and was one of the largest volcanic eruptions over the past 1 million years. With the aid of GPS and Interferometric Synthetic Aperture Radar (InSAR) data (both archived at UNAVCO), as well as electronic distance meter (EDM) data, the spatial and temporal extent of a significant period of uplift in the late 1990s was measured.

In our modeling of deformation at Long Valley, we investigate the time-dependent effect of viscous semi-solid fluids surrounding a purely fluid magmatic source. The continued availability of earlier and PBO-installed GPS data, along with SAR data at the UNAVCO facility will be invaluable for future modeling of the 1997-98 episode along with any near-future episode should it occur.

References:


This work was supported by Los Alamos National Lab (IGPP and Directors Fellowship) to AVN and NASA and ONR grants to THD (CSTARS publication #3).
Campaign and continuous GPS data were acquired from 1987 to 2005 to measure deformation of the Yellowstone-Snake River Plain volcano-tectonic province [Puskas et al., 2006]. The University of Utah, supported by UNAVCO and with collaborators, conducted seven campaigns between 1987 and 2003, occupying 140 stations and installing and operating 15 permanent GPS stations. The University of Utah permanent stations will be incorporated into an expanded EarthScope PBO network, improving coverage of Yellowstone. The GPS data revealed large and unexpected episodes of vertical deformation of the Yellowstone caldera. The caldera subsided at a maximum rate of 14 ± 3 mm/yr in 1987-1995. Vertical deformation shifted to the NW caldera boundary uplift at 5 ± 4 mm/yr for 1995-2000. For 2000-2003, caldera deformation switched to subsidence of up to 9 ± 6 mm/yr, yielding direct evidence of a restless caldera. Continuous GPS observations revealed a reversal to rapid caldera-wide uplift up to ~6 cm/yr from 2004 to 2006. These deformation episodes have been modeled [Vasco et al., 2007] by volumetric strain inversion revealing a mid-crustal source (6-10 km deep) of compression and expansion that coincides with the top of the tomographically imaged crustal magma body. Deformation is likely a result of accumulation and/or migration of hydrothermal fluids or magmatic crystallization.

Thirty kilometers west of the Yellowstone caldera, fault-normal extension continued across the Hebgen Lake fault at 3.1 to 5.3 mm/yr during the period 30 to 46 years following the 1959 M7.5 earthquake. Baseline data for 16 years of GPS observations combined with USGS trilateration data were used to model crustal rheology from the viscoelastic relaxation following this large event [Chang and Smith, 2006]. This model predicted post-seismic horizontal motion of 1 mm/yr within 40 km of the fault and uplift up to 2 mm/yr to the north of the fault. Using the rheology model, all of our data were corrected for time-dependent deformation caused by the M7.5 earthquake.

References

The research was supported by NSF Grants 0314298, 9725431, and 9316289.
Earthquakes Triggered by Silent Slip Events on Kilauea Volcano

Paul Segall » Stanford University
Emily Desmarais » Stanford University
David Shelley » Stanford University
Asta Miklius » Hawaiian Volcano Observatory
Peter Cervelli » Alaska Volcano Observatory

Slow-slip events, or ‘silent earthquakes’, have recently been discovered in a number of subduction zones including the Nankai trough in Japan, Cascadia, and Guerrero in Mexico, but the depths of these events have been difficult to determine from surface deformation measurements. Although it is assumed that these silent earthquakes are located along the plate megathrust, this hypothesis has not been proven. Slow slip in some subduction zones is associated with non-volcanic tremor, but tremor is difficult to locate and may be distributed over a broad depth range. Except for some events on the San Andreas fault, slow-slip events have not yet been associated with high-frequency earthquakes, which are easily located. We report on swarms of high-frequency earthquakes that accompany otherwise silent slips on Kilauea volcano, Hawaii. For the most energetic event, in January 2005, the slow slip began before the increase in seismicity. The temporal evolution of earthquakes is well explained by increased stressing caused by slow slip, implying that the earthquakes are triggered. The earthquakes, located at depths of 7 to 8 km, constrain the slow slip to be at comparable depths, because they must fall in zones of positive Coulomb stress change. Triggered earthquakes accompanying slow-slip events elsewhere might go undetected if background seismicity rates are low. Detection of such events would help constrain the depth of slow slip, and could lead to a method for quantifying the increased hazard during slow-slip events, as triggered events have the potential to grow into destructive earthquakes.

(a) Vectors show displacements for each event with 95% confidence intervals. Rectangles show surface projections of best-fitting dislocations found by non-linear optimization. Circles indicate relocated earthquakes accompanying the 2005 slip event. (b) Cross-section. Dashed lines represent dislocations from inversion of GPS data. The solid red line indicates the 2005 event with depth constrained by seismicity.

References

This work was supported by NSF grants EAR-9902875 and EAR-0537920.
Crustal Deformation Near Yucca Mountain, Nevada

B. P. Wernicke » Division of Geological & Planetary Sciences, California Institute of Technology
J. L. Davis » Harvard-Smithsonian Center for Astrophysics, Cambridge, MA
R A. Bennett » Department of Geosciences, University of Arizona
J. E. Normandeau » UNAVCO, Boulder, CO
A. M. Friedrich » Institute for Geology, University of Hanover, Germany
N. A. Niemi » Department of Geological Sciences, University of Michigan

As part of the BARGEN GPS network, we established a dense cluster of GPS sites in the Yucca Mountain area. The cluster was installed in 1999 to provide the most reliable measurements possible of geodetic strain patterns across the nation’s only proposed permanent repository for high-level radioactive waste. The accuracy of the measured horizontal velocities is ~0.2 mm/yr [Davis et al., 2003]. The network lies astride a boundary between the geodetically stable central Great Basin and the active western Great Basin, which at the latitude of Yucca Mountain is undergoing distributed right-lateral shear at a rate of ~60 nstrain/yr. The GPS solution (1999–2003) from the Yucca Mountain cluster (Figure 1) yields a velocity field characterized by nearly homogenous N20°W right-lateral shear of 20 ± 2 nstrain/yr (net velocity contrast of 1.2 mm/yr across a 60 km aperture) in the vicinity of the proposed repository site [Wernicke et al., 2004]. Comparison of time series of continuous results with earlier campaign surveys [Wernicke et al., 1998] indicating 50 nstrain/yr of west-northwest extension from 1991 to 1997 suggests that the more rapid rates were in part transients associated with the 1992 Ms 5.4 Little Skull Mountain earthquake. Postseismic motions do not appear to affect the 1999–2003 velocity field in either campaign or continuous data. The observed magnitude of the velocity contrast across the area, the overall linearity of the gradient, and the large area of undeforming crust to the east of Yucca Mountain are difficult to explain by elastic bending of the crust associated with the Death Valley fault zone, a major right-lateral strike-slip fault about 50 km west of the repository site. These observations, along with apparent local variations in the velocity gradient, suggest that significant right-lateral strain accumulation, with displacement rate ~1 mm/yr, may be associated with structures in the Yucca Mountain area (Figure 2). The absence of structures in the area with equivalent late Quaternary displacement rates underscores the problem of reconciling discrepancies between geologic and geodetic estimates of deformation rates.

References


This work was supported by the U.S. Department of Energy and the National Science Foundation.

Figure 1. Horizontal velocity field (in a local reference frame) for the Yucca Mountain cluster of BARGEN. Locations of sites MILE and WAHO [Wernicke et al., 1998] are indicated by white triangles. The star indicates the epicenter of the 29 June 1992 Ms 5.4 Little Skull Mountain earthquake. The dashed line indicates the location of the model Death Valley fault of Figure 2 [Wernicke et al., 2004].

Figure 2. N20°W projection of velocities and the two-fault model of Wernicke et al. [2004] (solid curve). The second fault is located at x = +54 km. The dotted curve shows effects of a single fault at x = 0, representing the Death Valley Fault.
Magmatic Systems

InSAR and GPS Observations of Anomalous Uplift Under the Rim of Yellowstone Caldera

Charles Wicks » U.S. Geological Survey, Menlo Park, CA

An anomalous mode of surface deformation in Yellowstone, shown in Figure 1, lasted from 1996 through 2002 (Wicks et al., 2006). The deformation signal in a previous InSAR study of Yellowstone (Wicks et al., 1998) was mostly contained within the caldera rim. A deep narrow shallow dipping sill model (Figure 1) fits the data better than a point source or a prolate ellipsoidal source. We interpreted this source as magma accumulation at a magma outlet beneath the Yellowstone volcanic system. The deformation data in an interferogram is one dimensional, in the direction of the line-of-sight (LOS, Figure 2) to the satellite. Horizontal deformation measurements allow better determination of the most appropriate deformation source, so we incorporated campaign GPS measurements (Meertens et al., 2000, collected by the University of Utah) to simultaneously model the InSAR and GPS measurements of the uplift episode (Figure 2).

Incorporation of the GPS data led us to conclude that at the 95% confidence level we could not distinguish between a deep shallow dipping sill (Figure 1) and a deep narrow shallow-dipping prolate ellipsoid as a deformation source for the uplift. Thus, we cannot distinguish between magma transport along an interface and magma transport through a nearly horizontal conduit.

Figure 1. An interferogram calculated from two European Space Agency ERS2 satellite images acquired during the summers of 1996 and 2000. The short-dash line marks the location of the rim of the Yellowstone caldera that formed ~640,000 years ago. The double-dash line shows the boundary of the Yellowstone National Park. The interferograms shows over 70 mm of uplift under the north caldera rim. Yellow lines show the roads in the park area. The white box shows the location of the best-fit sill model.

Figure 2. The colored squares are data parsed from an unwrapped stacked interferogram from summer 1995 to summer 2000 (Wicks et al., 2006). GPS vectors from Univ. of Utah GPS campaigns in 1995 and 2000 (Meertens, 2000) are shown in black with 95% confidence ellipses. The red vectors show the calculated displacement from the model that best fits GPS and InSAR data (a long narrow sill, Figure 1). Black ellipses show where the calculated values do not fall within the 95% ellipses and gray ellipses show where the calculated values do fall within the 95% ellipses. The arrow labeled “LOS” shows the line-of-sight direction to the satellite, which is about 23 degrees from vertical in the center of the scene. The arrow perpendicular to the LOS vector shows the flight track of the satellite.

Collection of the GPS data, archived at UNAVCO, was funded by an NSF grant to Dr. Robert Smith (University of Utah).

REFERENCES


Mechanical Modeling of Volcanic Deformation: Application to Mauna Loa

Sang-Ho Yun » Department of Geophysics, Stanford University
Paul Segall » Department of Geophysics, Stanford University
Howard Zebker » Department of Geophysics, Stanford University
Falk Amelung » Division of Marine Geology and Geophysics, University of Miami

We model crustal deformation at Mauna Loa volcano using boundary element methods constrained by Interferometric Synthetic Aperture Radar (InSAR) data. A total of thirty interferograms are stacked to reduce atmospheric noise for four different look angles (two ascending and two descending with look angles from 23.5 to 43.5 degrees) from the Radarsat satellite. The overall time span of the interferograms is November 2001–September 2005, and the maximum stacked line-of-sight velocities (range decrease) are from 5.1 cm/year (ascending beam 3) to 7.9 cm/year (descending beam 6). We fit the four interferograms with one planar dike-like and one finite spherical magma chamber that are interconnected and share the same excess magma pressure. Simulated annealing inversion with binary parameters (Yun et al., 2006) allows solving for the excess pressure and the geometry of the deformation source. Topography correction (Williams and Wadge, 2000) was applied during the inversion. The estimated excess pressure is about 1.76 MPa, and the spherical magma chamber is estimated to be at a depth of about 4.66 km below the summit of Mauna Loa. The excess pressure constrains the radius of the spherical chamber, which is estimated to be about 1.15 km. The dike plane aligns with Mauna Loa’s southwest rift zone, and the maximum dike opening rate is about 30 cm/year. The volume increase rates of the dike and the spherical magma chamber are 24.7 x 10^6 m^3/year and 0.3 x 10^6 m^3/year respectively. This model explains 96% of data variance with an RMS error of 2.40 mm/year.

References


This work was supported by NSF Grants EAR-0511035 and EAR-0346240.