# Documenting dome and glacier changes from the 2004-2008 eruption at Mount St. Helens, USA

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During the 2004-2008 eruption at Mount St Helens, WA, 26 digital elevation models (DEMs) were created from vertical aerial photographs. These DEMs were used to track volume and rates of growth of a new lava dome as well as changes in Crater Glacier, which was displaced by the growing lava dome. The estimated dome volume reached a peak in early September, 2007, of about 95 x $10^6$ $m^3$. More recent estimates of the dome volume decreased to about 90 x $10^6$ $m^3$, the decrease presumably due to settling and compaction of abundant dome rock talus. These estimates are approximations of total volume, because, the dome bore and grew through Crater Glacier, leaving us to assume the dome had vertical sides beneath the glacier surface. Rates of dome growth decreased from about 6 $m^3$ / sec early in 2004, to about 0.1-0.2 $m^3$ / sec in early 2008 as the eruption waned. Constructing and differencing of consecutive DEMS was used to track dome growth as part of a multidisciplinary monitoring effort throughout the eruption. The dome-volume estimates also served as a key data set to constrain seismogenic extrusion models and to compare against geodetic surface-deflation volume to constrain magma chamber behavior.

As the dome grew, it split Crater Glacier into a two parts, and squeezed east and west arms of the glacier against the crater walls. DEMs showed the glacier arms nearly doubled in thickness and then thinned as the glacier ice flowed downslope to the north. Despite early explosions through the ice and exposure of the glacier to extruding hot dome rock, the glacier lost only about 15% of its pre-eruption volume (from about 70M $m^3$ to 60M $m^3$). By 2012, the glacier volume had regained about 91% of its pre-eruption volume (to about 64M $m^3$).

Photogrammetric software that uses robust image-matching algorithms to produce 3D surfaces automatically from overlapping photographs is now a mainstay of our ongoing volcano monitoring. Vertical aerial photographs are taken annually at a consistent 1:12,000 scale in the autumn at the time of maximum glacier ablation; prior to new winter snow. With overlapping pairs of photographs and carefully planned GPS ground control, we use the software to generate surfaces in minutes that extend over the entire 1980 crater. Preliminary tests show that surfaces generated from those images are of comparable resolution and accuracy to those generated from vertical aerial photographs. Oblique hand-held images offer ease of image capture and unobscured views at times when steam plumes and clouds obstruct vertical aerial photography, a common obstacle early in the eruption. The combined use of vertical and(or) oblique photographs provide substantial flexibility to our monitoring program. These technological advances have repositioned photogrammetry into the realm of near real-time monitoring and hazard assessment.