Geophysical Research Abstracts,
Vol. 11, EGU2009-1012-3, 2009
EGU General Assembly 2009
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Three-dimensional stochastic adjustment of volcano geodetic network in Arenal volcano, Costa Rica

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Volcano geodetic networks are a key instrument to understanding magmatic processes and, thus, forecasting potentially hazardous activity. These networks are extensively used on volcanoes worldwide and generally comprise a number of different traditional and modern geodetic surveying techniques such as levelling, distances, triangulation and GNSS. However, in most cases, data from the different methodologies are surveyed, adjusted and analysed independently. Experience shows that the problem with this procedure is the mismatch between the excellent correlation of position values within a single technique and the low cross-correlation of such values within different techniques or when the same network is surveyed shortly after using the same technique. Moreover one different independent network for each geodetic surveying technique strongly increase logistics and thus the cost of each measurement campaign.
It is therefore important to develop geodetic networks which combine the different geodetic surveying technique, and to adjust geodetic data together in order to better quantify the uncertainties associated to the measured displacements. In order to overcome the lack of inter-methodology data integration, the Geomatic Institute of the University of Applied Sciences of Western Switzerland (HEIG-VD) has developed a methodology which uses a 3D stochastic adjustment software of redundant geodetic networks, TRINET+. The methodology consists of using each geodetic measurement technique for its strengths relative to other methodologies. Also, the combination of the measurements in a single network allows more cost-effective surveying. The geodetic data are thereafter adjusted and analysed in the same referential frame. The adjustment methodology is based on the least mean square method and links the data with the geometry. Trinet+ also allows to run a priori simulations of the network, hence testing the quality and resolution to be expected for a determined network even before it is built. Moreover, a posterior analysis enables identifying, and hence dismissing, measurement errors (antenna height, atmospheric effects, etc.).

Here we present a preliminary effort to apply this technique to volcano deformation. A geodetic network has been developed on the western flank of the Arenal volcano in Costa Rica. It is surveyed with GNSS, angular and EDM (Electronic Distance Measurements) measurements. Three measurement campaigns were carried out between February and June 2008. The results show consistent and accurate output of deformation and uncertainty for each of the 12 benchmarks surveyed. The three campaigns also prove the repeatability and consistency of the statistical indicators and the displacement vectors. Although, this methodology has only recently been applied to volcanoes, we suggest that due to its cost-effective high-quality results it has the potential to be incorporated into the design and analysis of volcano geodetic networks worldwide.