



Cities on Volcanoes 9
November 20-25, 2016
Puerto Varas, Chile



Understanding volcanoes and society: the key for risk mitigation
Strategically located tiltmeter provides strong

deformation signals before Vulcanian eruption onset at Tungurahua volcano, 2013-2016

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Key words: Vulcanian explosions, Tungurahua, Ecuador, tiltmeter data, early warning

Tiltmeter data provides a powerful tool to characterize deformation volcanoes, allowing the tracing of magma transport through the crust over timescales and depths. Surface deformation at active Tungurahua has been inferred as caused by pressure changes within the magmatic system at depth or by shear stress caused by magma tracking up conduit. Tungurahua volcano is an andesitic strato-volcano with historical eruptions of VEI 2 to 4. It has been erupting since 1999 and is well-monitored by the Instituto Geofísico, EPN-Quito.

Five tilt sensors are installed on the volcano's flanks. However the station *RETU*, located at 3950 meters altitude and only 2.5 km radial from the conduit has recorded the most valuable data. Before strong Vulcanian outbursts at Tungurahua in July 2013 we observed significant positive tilt changes of hundreds of microradians. This same pattern was later observed in October 2013 and February 2014, and before subsequent episodes. Besides the pattern of strong positive tilt that may or not have been synchronous with long-period seismicity, the precursor most foretelling before eruption onset have been strong tilt reversals 3-8 days before eruption. This reversal is negative and we believe represents a stalling out of the ascending magma slug underneath an impervious conduit plug that is presumably heated and compressed. Overpressures beneath the plug then causes it to fracture, the process represented by tell-tale swarm of shallow VT fracture and LP seismic events, before an ensuing violent Vulcanian explosions. Based on these tilt patterns and the sudden increase in accumulated seismic energy (RSAM) of the swarms we have provided early warnings to high-risk populations. Our results show that tiltmeters can give us a forecast from days to weeks. However it is critical for both tilt and seismic instruments to be strategically-deployed near source in order to provide convincing short-term warnings.