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Seismic observations and multidisciplinary interpretation of their analysis: understanding the unrest at Turrialba volcano (Costa Rica)

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Turrialba is a basaltic-andesitic stratovolcano, 3340 m a.s.l., in the Cordillera Volcánica Central in Costa Rica, which has been significantly active for more than 10,000 years. Although most of the recent geologically recorded eruptions were phreatic or phreatomagmatic explosive eruptions, there are also important records of large Plinian eruptions. Moreover, it has a record of large gravitational collapses, representing a very significant potential hazard to nearby populated areas.

Since the last eruption in 1864-1866, volcanic manifestations were limited to low temperature fumarolic degassing (continuous since 1980) through its Central and West craters. After many years of quiescence, from 1996 onward, its activity has been progressively increasing, with the occurrence of several seismic swarms. An increment in the number of fumaroles and level of degassing has been observed at the occurrence of each seismic swarm. New fumaroles have appeared in both Central and West craters (the latter now being the most active), and in the fracture system in between, showing sulfur deposits and progressively increasing degassing levels.

The maximum seismic activity to date was recorded by the permanent seismic network in mid 2007 with swarms of up to thousands volcano-tectonic-type of events/day. Following this, temperatures measured at fumaroles in the bottom of the Western crater have increased from 90° to 280° C , while pH of fumarolic condensates at the same crater has decreased to values as low as 0,55 and their solute concentrations have largely increased. Changes in the fumarolic gas composition, isotopic composition of the condensates as well as in rainwater samples collected in the surroundings of the volcano have been showing a progressively higher magmatic signature, interacting with a shallow hydrothermal system. Since late 2007, SO2 flux measured with mini-DOAS has increased two orders of magnitude. The enhanced gas discharge at Turrialba volcano has caused significant interference on troposphere O3 measurements at 2-3 km altitude ∼50 km W from the volcano, detected by the Ozone Monitoring Instrument (OMI) on NASA's EOS-Aura satellite. The current geodetic network at Turrialba volcano (comprising two small EDM networks, leveling lines, an electronic tiltmeter and periodical GPS campaigns) measuring during the reawakening of the volcano for the past decade, is very limited but it has detected an inflationary trend in the crater area in the last 2 years.

The 2007 peak in seismic activity has marked an important change in the seismicity patterns as well as in the geochemical, geodetical and field observations. Previous to it, VT type events have been mainly recorded, typically showing a spindle shape waveform most likely due to the strongly scattering volcanic environment. Since late 2007, gas-driven deep impulsive events have dominated the seismicity, often followed by episodes of harmonic tremor.

In this work, we present a summary of the activity of the volcano and the data collected during more than 10 years of monitoring, with particular emphasis on the changes occurred over the last 2 years. We show results from analysis of the seismic data collected by the seismic permanent network and by a small aperture short-period seismic array deployed in 2008, as well as the initial observations recorded by several broad-band arrays due to be deployed at the end of January 2009. Integrating the geochemistry, geophysical, geodetical, and field data available, we present an interpretation of the seismic observations and the current status of the volcano.