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Utilization of the Auxiliary Seismic Station APG (AS37) for the Analysis of Seismicity Induced by Tropical Depressions Eta and Iota in the Karst Region of Northern Guatemala

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INTRODUCTION AND MAIN RESULTS

The 2020 Atlantic hurricane season was highly active, with Eta and Iota causing severe floods and landslides in Guatemala, leading to deaths, disappearances, and damage amid COVID-19.

INSIVUMEH's RSN recorded induced seismicity in Alta Verapaz and Quiché, linked to floods in karst systems. Analyses suggest activation of minor seismic sources, marking Guatemala's first study of meteorologically induced seismicity.

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Abstract

The 2020 Atlantic hurricane season was among the most active on record, with tropical storms Eta and Iota causing disasters in Nicaragua, Honduras, and Guatemala. In Guatemala, floods and landslides led to fatalities, disappearances, and severe damage to housing and livelihoods, worsening a crisis already strained by COVID-19.

During and after the storms, INSIVUMEH's Red Sismológica Nacional (RSN) recorded seismic activity in Alta Verapaz and Quiché, areas heavily impacted by flooding, raising public concern. The APG station (AS-037) in Baja Verapaz was key for monitoring.

This study analyzes the link between seismicity and regional floods, emphasizing karst geology and hydrogeological systems. Comparable studies in other karst environments attribute this to sudden flooding, pore pressure changes, and diffusion, consistent with the observed seismicity.

Epicenter distribution and correlation of earthquake families indicate activation of minor seismic sources, marking the first instrumental study of meteorologically induced seismicity in Guatemala's karst regions.

Geological description and seismicity

The territory of Guatemala lies between the North American and Caribbean plates. The northern region, including Alta Verapaz (AV) and Quiché (QUI), is part of the Maya Block (Fig. 1a), dominated by carbonate rocks from various geological formations (Fig. 1b), forming a complex karst system.

The red box in Fig. 1a outlines the seismicity area, with error ellipses shown in Figure 1b. The sequence groups into three clusters (A, B and C), linked to floods caused by the approach of tropical storms Eta and Iota.

a)
b)

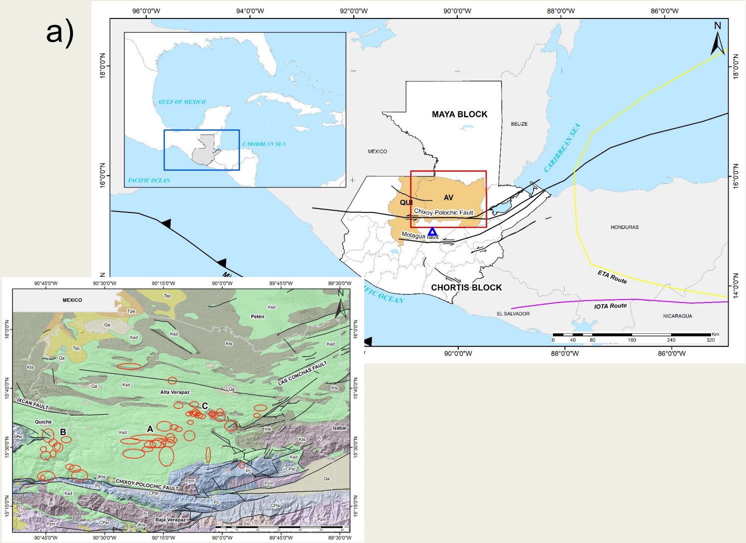

Figure 1. a) Tectonic features and tracks of Eta and Iota. Blue triangle: APG (AS037) station. b) Geology of the study area and recorded seismicity.

Karst flooding

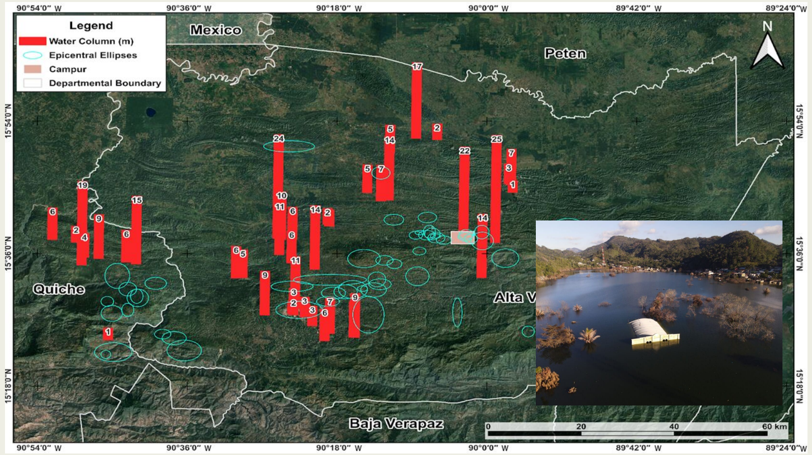

Figure 2. Flood heights (inset: Campur, photo by Carlos Coc)

Eta made its closest approach to Guatemala on November 5, producing up to 173 mm of rainfall and cumulative totals of 535 mm. Between November 17 and 22, Iota generated rainfall exceeding 60 mm, with totals of 375 mm. These rains, on already saturated soils, exceeded the karst system's capacity, triggering severe flooding, such as in Campur, where water reached ~22 m. These floods coincided with unusual seismicity in the affected region.

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Temporal correlation of rainfall and seismicity

The short-period seismic station AVCB in Cobán, Alta Verapaz, together with the colocated meteorological station, allowed for a temporal analysis of the relationship between rainfall and seismicity. The earthquakes were approximately distributed into three clusters. In central cluster A, the first events were recorded following the rainfall generated by Eta, and this seismicity continued throughout the sequence. The second seismic episode, following Iota, was recorded mainly in clusters B and C. Seismicity persisted into December, with epicenters located in cluster C and south of cluster B, some possibly linked to the Chixoy-Polochic Fault.

a) b)

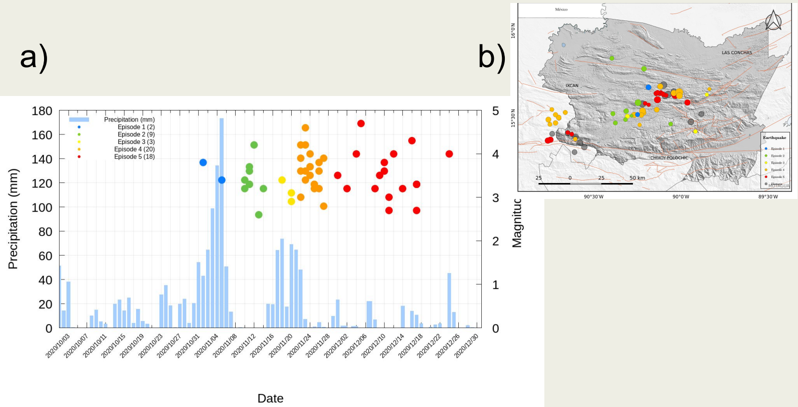

Figure 3. a) Temporal evolution of rainfall and seismicity. b) Epicentral distribution.

Repeating earthquakes

a) b)

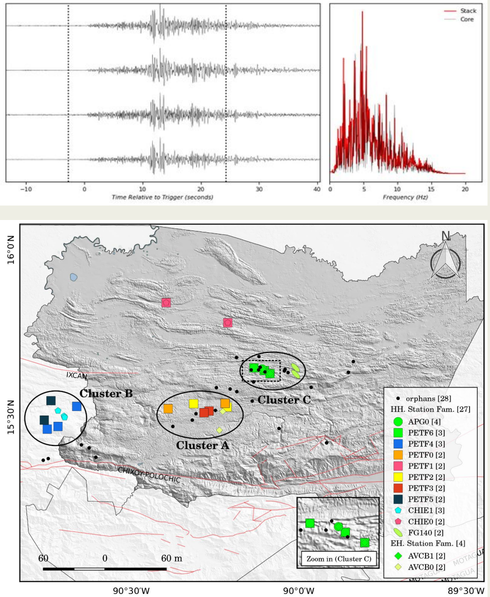

Figure 4. a) Family detected at APG. b) Location of the identified families.

Repetitive earthquakes were identified using REDPy, which groups events based on waveform similarity. Using records from five stations (APG, PETF, CHIE, FG14, AVCB), 10 families were detected across clusters A, B, and C, with the largest family in cluster C. Twenty-eight earthquakes remained unassociated (“orphans”).

Operational issues at the APG station limited detection during the peak seismicity episode in November.

Conclusions

We associate the unusual seismicity recorded in November–December in northern Guatemala’s karst region with widespread flooding from tropical storms Eta and Iota, exploring possible triggering mechanisms based on timing: direct hydraulic connection to the seismic sources, a coupled effect of direct hydraulic connection with short-range pore fluid diffusion, and a more delayed diffusion process.

Waveform correlation from five stations identified ten families potentially linked to fracture or fault activation in a tectonically predisposed environment.

This karstic setting’s ability to nucleate significant earthquakes in response to sudden, prolonged flooding represents a notable seismic hazard, warranting further study given the potential for intense rainfall under climate change.

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