Seismological Models and Seismicity Patterns in the Kivu Rift and Virunga Volcanic Province (D.R. Congo / Rwanda)

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This work is part of the ongoing PhD thesis by Mr. Josué Subira (seismologist at GVO - Goma Volcano Observatory) involving RMCA (Belgium), ECGS/NMHN (Luxembourg), ULB (Belgium) and Univ. Liège (Belgium) (thesis defence planned in 2024)

Context

- The Kivu rift is located in the bordering region of the Democratic Republic of Congo and Rwanda, in the Western branch of the East African Rift
- Active volcanoes Nyiragongo and Nyamulagira in the Virunga Volcanic Province threaten a densely populated area (>> 1 millions inhabitants) →
- Destructive earthquakes can also affect the region, as it was the case recently in 2015 in Katana (M_W 5.7) along the southwestern shore of Lake Kivu
- Fundamental importance of monitoring the seismicity in this region but no reliable permanent network up to the KivuSNet deployed in 2013-2022
- Real-time monitoring in 2015-2022, encompassing the May 22, 2021 Nyiragongo's flank eruption and subsequent 1-week, 25-km long dyke intrusion

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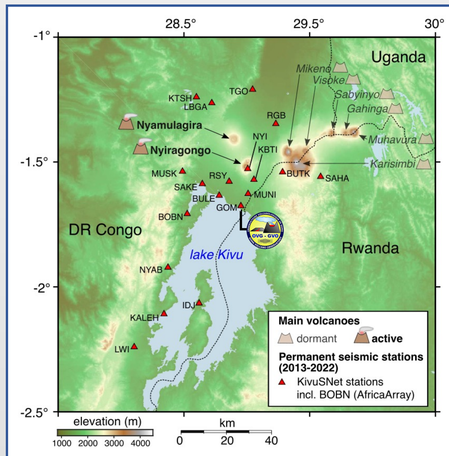
1. The Tool : KivuSNet (2013-2022)

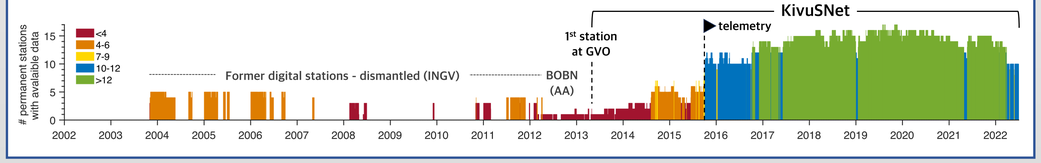
Initiated & maintained by Belgian/Lux research teams with DRC/Rwanda institutes → 1st dense, permanent, broadband, telemetered network for Goma Volcano Observatory (GVO) with data acquisition/analysis in real-time



Some Related Articles

Oth et al. (2016) *Seismological Research Letters*

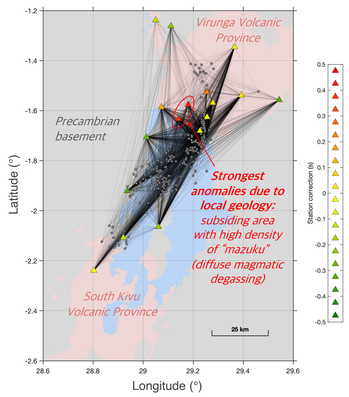
Subira et al. (2023) *Bulletin of Volcanology*



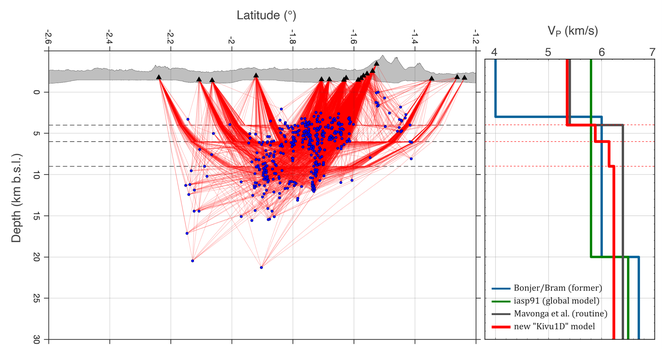
2. The Seismological Models : 1D Velocity & Magnitude Scale

- From a selected dataset of well-recorded ~400 events, solving the coupled hypocenter-velocity inverse problem following Kissling et al. (1994, JGR) allows to get a suitable 1D velocity model for absolute earthquake location called a "minimum model".
- Station correction terms (i.e., delays to subtract to the observed arrival times) are estimated in the inversion process to compensate for near-surface and large-scale heterogeneities in the crust not considered in the 1D solution.
- The first local magnitude scale for the region has also been calibrated from the same selected dataset (not shown here).

Selected events (gray circles), seismic ray paths (black) and final P-wave station delays

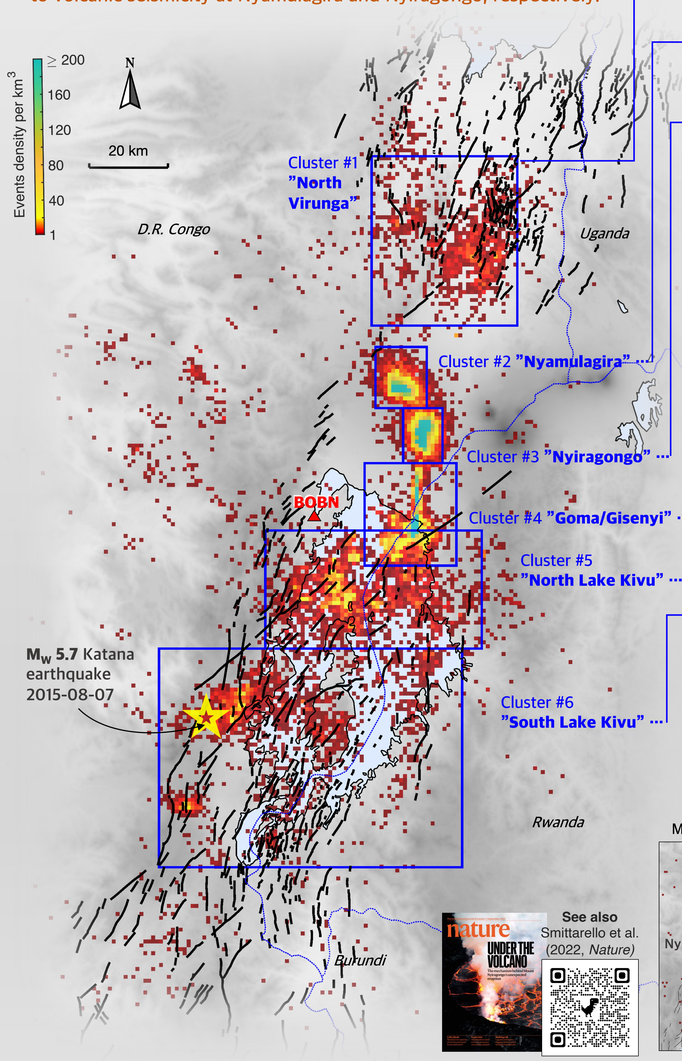


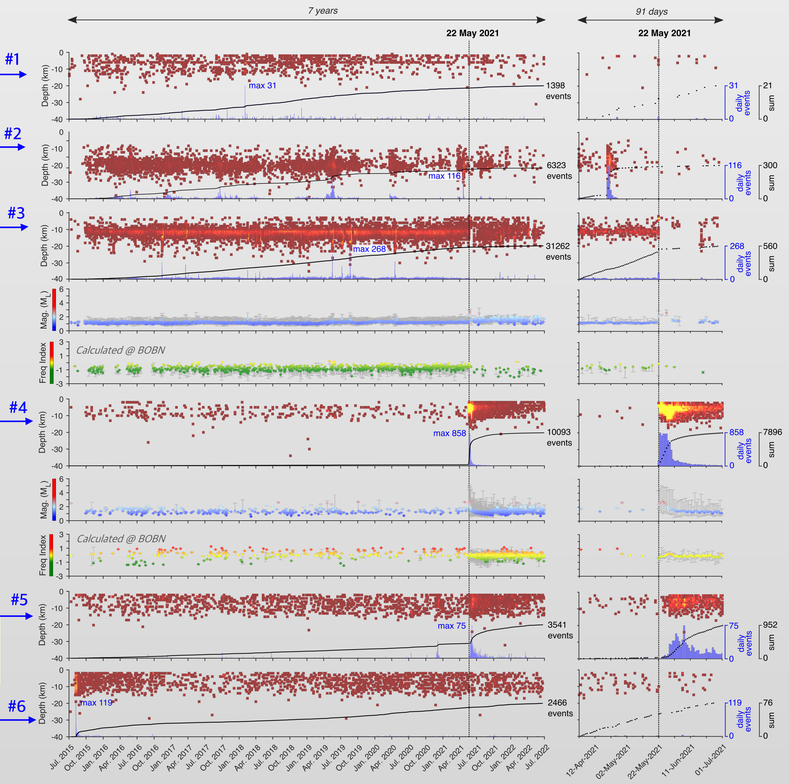
(Left) Depth distribution of events and seismic ray paths using the new 1D minimum model "Kivu1D". (Right) Final P-wave velocity model "Kivu 1D" (red) plotted against available velocity models for the region: The former Bonjer/Bram (1970/1975) model (blue), the iasp91 global reference model (green) and the routine model used at GVO (Mavonga et al., 2010) derived from receiver function analysis at two dismantled stations (dark gray).



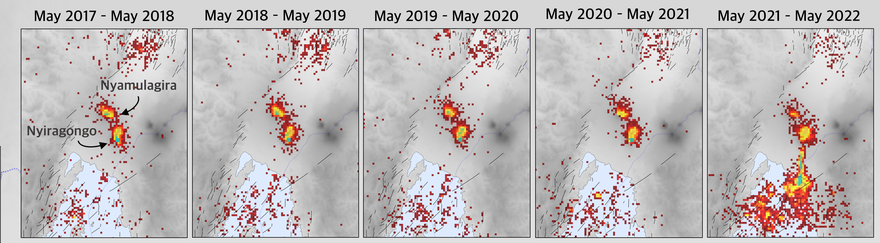
3. Seismicity Patterns 2015 - 2022

6 spatial clusters of seismic events : #1, #4, #5 and #6 dominated by tectonic seismicity related to rift dynamics, #2 and #3 corresponding to volcanic seismicity at Nyamulagira and Nyiragongo, respectively.





Daily events density per km³ plotted against the depth for the six clusters #1 to #6. The color scale is the same as the one used for the map on the left. Count (blue histogram) and cumulative sum (black dots) are plotted in the same panels (see the y-scale on the right). For clusters #3 (Nyiragongo) and #4 (cities of Goma/Gisenyi + northern portion of lake Kivu), the timeseries of local magnitude and frequency index (FI, e.g., Matoza et al., 2014, GRL) are provided. Daily median are indicated by colored markers and error bars give the range from min to max values. The FI, calculated at station BOBN (see map), conveys the frequency content of event onset related to path/source, green to red for low (<4 Hz) to high (>4Hz).



See also Smittarello et al. (2022, *Nature*)

Seismic events density per km³ between July 2015 and July 2022 (color scale red to green). The main fault lineaments are plotted as solid black lines (source : Smets et al., 2016, Tectonophysics).
The five pictures on the bottom right represent a zoom around the Virunga Volcanic Province for 5 consecutive year-long periods from May 22, 2017 to May 22, 2022. The dyke intrusion starting on May 22, 2021 is clearly visible.