Local infrasound monitoring of lava eruptions at Nyiragongo volcano (D.R. Congo) using urban and near-source stations

Julien Barrière[1], Adrien Oth[1], Nicolas d'Oreye[1,2], Josué Subira[3,4,5], Delphine Smittarello[1], Hugues Brenot[6], Nicolas Theys[6], and Benoît Smets[3,7]

[1] ECGS, Luxembourg; [2] NMNH, Luxembourg; [3] RMCA, Belgium; [4] Univ. Liège, Belgium; [5] GVO, D.R. Congo; [6] BIRA-IASB, Belgium; [7] Vrije Univ. Brussel, Belgium I Contact : J. Barrière (julien.barriere@ecgs.lu)

Related Article

Barrière et al. (2023). Geophysical Research Letters, 50, e2023GL104664.

Context

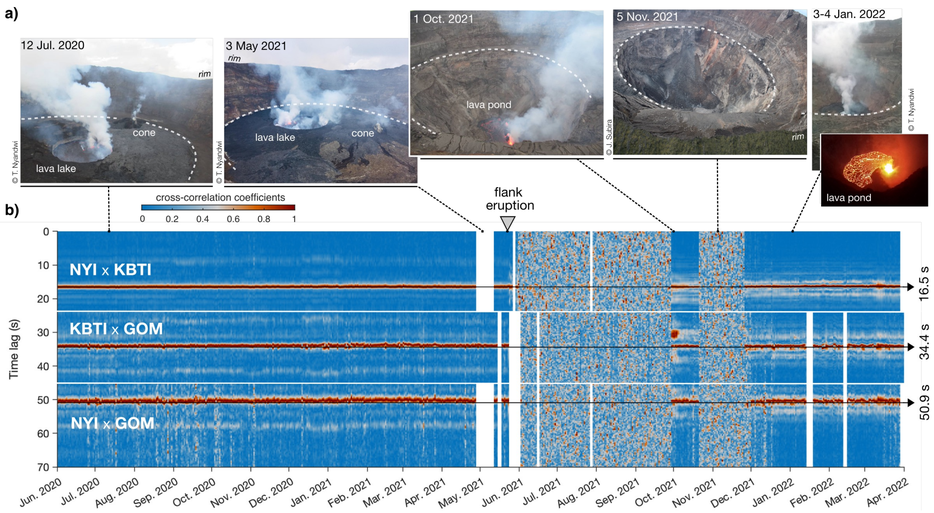
- During eruptions, volcanoes produce air-pressure waves inaudible for the human ear called infrasound
- Monitoring long-living lava effusion as observed at open-vent volcanoes needs close-range instruments (e.g., <15 km)
- Nyiragongo (Kivu rift region) towers above the cities of Goma (~1 million inh.) and Gisenyi (~200 000 inh.)
- Nyiragongo hosted the world's largest lava lake up to 2021, drained during its 3rd known flank eruption in May 2021

→ Telemetered infrasound stations deployed in 2016-2022: **GOM** (Goma volcano observatory), **KBTI** (Virunga park rangers' building), **NYI** (summit)

Key Points

- Nyiragongo is a permanent emitter of infrasound that pauses during rare flank eruptions
- Intra-crater lava eruptions (lava lake, spatter cone, lava pond) are detected up to the Goma Volcano Observatory (GVO) in a dense urban area ~17 km away
- Joint analysis with space-based observations (crater's morphology, SO_2 emissions, thermal hotspots) over the period 2018-2022 helps decipher unrest

1. Detecting Nyiragongo's Continuous Infrasound Signature



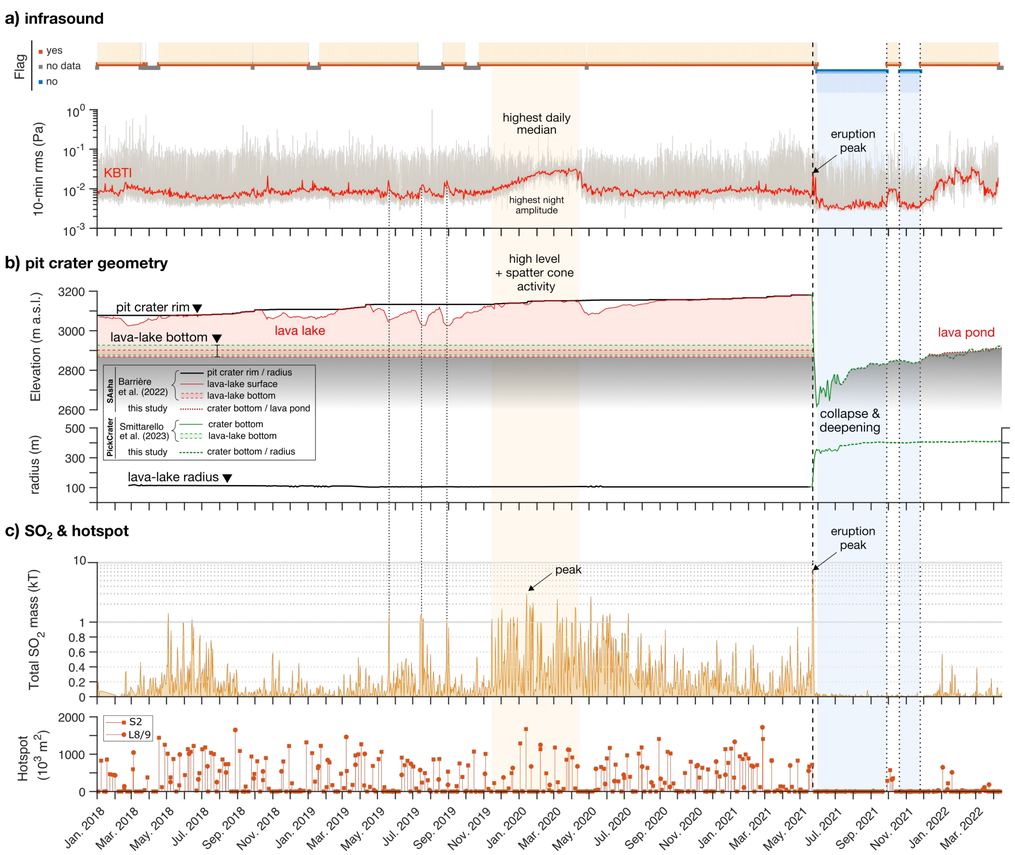
a) Pictures of Nyiragongo's crater **b)** Normalized Hilbert envelopes of cross-correlation functions (CCFs) displayed in a plane "date versus time lag." Daily windows with less than 10% of calculated CCFs are ignored (blank parts). Only sections around the single maxima for each station pair are plotted. All single CCFs are scaled by their maximum (in red). Theoretical travel-times from a source at Nyiragongo are indicated by black lines.

- Continuous tremor (i.e., a persistent pressure perturbation) known to be associated with lava-lake activity *(e.g., Barrière et al., 2018, Frontiers; Barrière et al., 2019, EPSL; Valade et al., 2018, EPSL)*
- Detection with small aperture array (~20 m) for frequencies > 1 Hz well noticed at KBTI but hampered at GOM due to urban noise and large distance (~17 km) *(see related article Barrière et al., 2023, GRL)*

→ **Looking for continuous signals at each station ("masked" at GOM) in a low frequency band (0.4-2 Hz)**

- Cross-correlation Functions (CCFs) of successive 10-min segments are computed for the three station pairs
- Clear single maxima (red color range in **b**) are observed at positive and nearly constant time lags
- Remarkably fit theoretical differential travel-times from a persistent signal generated at Nyiragongo's crater

2. Intra-Crater Eruptive Activity 2018-2022



a) Infrasound flag indicator for Nyiragongo's source derived from CCFs results (see left figure & article for details). Below, 10-min RMS amplitude at KBTI (gray) and moving daily median (red). **b)** Pit crater geometry (elevation and radius) using SAsha and PickCraterSAR methods (Barrière et al., 2022, JGR; Smittarello et al., 2023, JGR), including variations of the lava-lake level (in red). **c)** For Nyiragongo, space-based daily solutions for SO_2 emissions obtained from TROPOMI (Theys et al., 2019, Sci. Rep.) and thermal hotspots (S2 stands for Sentinel-2, L8/9 for Landsat-8/9) using HOTMAP (Murphy et al., 2016, R. Sens. Env.)

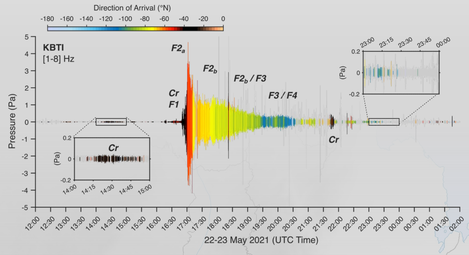
→ **MAIN OBSERVATIONS**

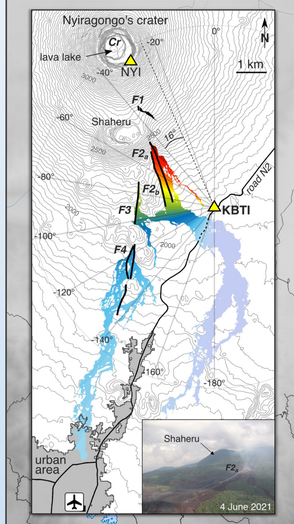
- Variations of infrasound amplitude linked with SO_2 emissions, both being related to high lava-lake levels and drops *(see Barrière et al., 2022, JGR, for discussion about these drops due to repetitive deep magmatic intrusions)*
- Lowest levels of infrasound amplitude at KBTI and loss of correlation between stations (flag = 0) when the crater was deep and empty after the May 2021 flank eruption (confirmed by rare pictures and satellite data)
- Both renewal of intra-crater activity on 28 September and 25 November 2021 first identified in the infrasound records, further validated by thermal imagery despite cloudy conditions or by visual inspection at the summit by GVO

→ **DAILY MONITORING ASPECT**

Harsh field environment implies the need of an accessible and protected location for sensor deployment, which likely resides within the confines of the city (limited access to NYI and KBTI in 2023 due to civil war). Deploying another city-based station in Goma could be a strategy to extract information through a unique pair of urban stations.

3. May 2021 flank eruption

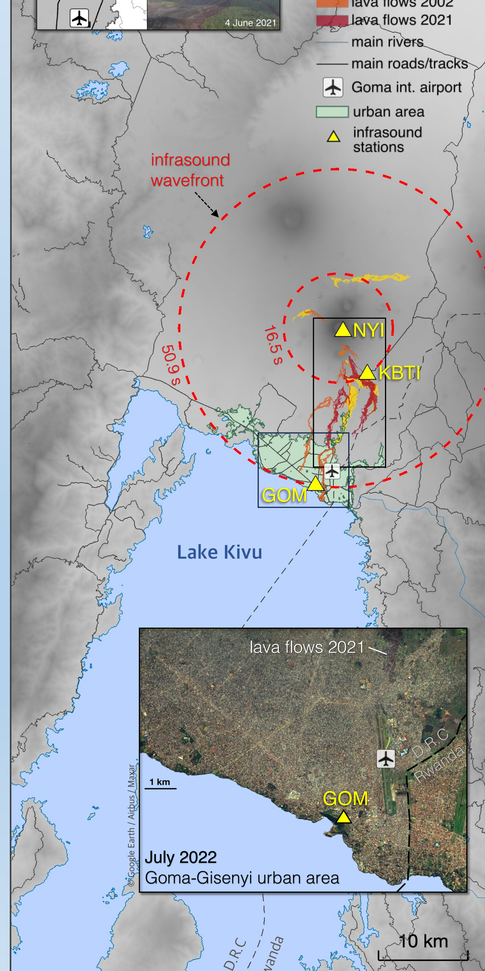




← Tracking the opening of the eruptive fissures using KBTI array

+ Inverting low-frequency (< 1Hz) infrasound data for estimating the synchronous draining of the lava lake (not shown here)

article in prep ...



ECGS | CEGS · AFRICA GEORISKA museum · LIÈGE université · VUB

AGU23 San Francisco, CA & Online Everywhere 11-15 December 2023

Poster V11D-0101