AGU FALL MEETING
New Orleans, LA & Online Everywhere
13–17 December 2021

# Propagation and arrest of the May 2021 lateral dike intrusion at Nyiragongo (D.R. Congo)

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# Outline

From Lake Kivu to Nyiragongo

- Ground Networks and Remote Sensing
- The eruption and its impact
- Absence of precursors
- A textbook-like dike
- Progressive Crater collapse
- Propagation Arrest
- What's next ?

Nyamulagira and Nyiragongo lights seen from Goma

# Ground Networks: Seismic, Infrasound, GNSS

KivuSNet (broadband seismic and infrasound telemetered network)

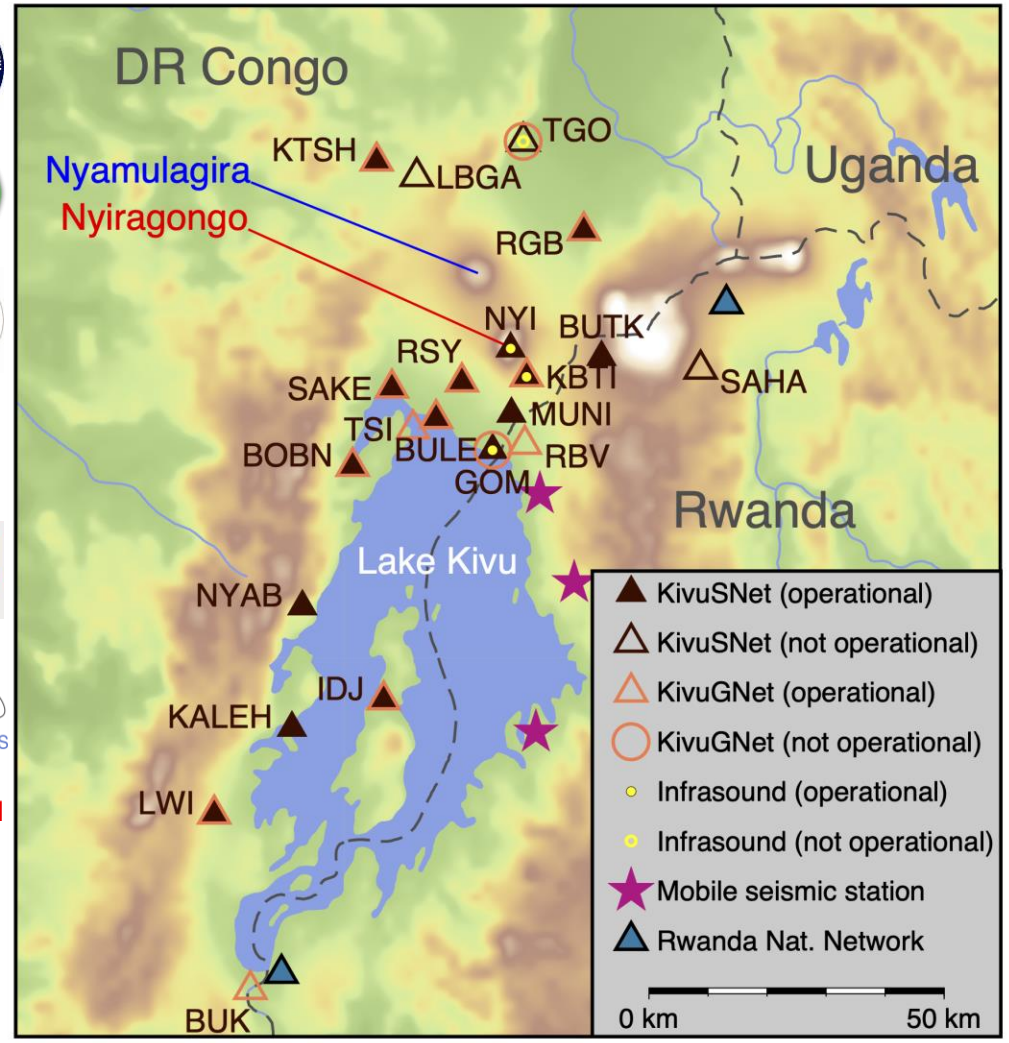
→ **Up to 14 real time seismic stations available**

→ **Up to 7 infrasound sensors available**

KivuGNet (GNSS telemetered network)

→ **Up to 13 GNSS stations available**

**Simultaneous seismic & infrasound data acquisition through *Seedlink* servers at GVO (DRC), RMB (Rwanda) and ECGS (Lux.).**




(*) The Rwanda National Seismic Network was designed and installed by ECGS. Stations in Huye and Kigali not visible on this map.



(Oth et al., SRL, 2017 )
(Geirsson et al., JAES, 2017)

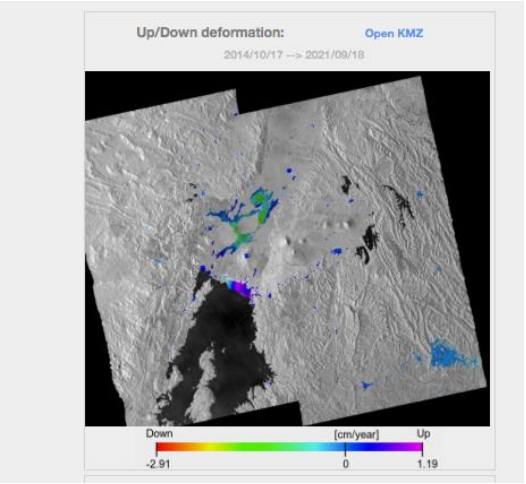
# Automated Tools: MasTer

**InSAR mass processing + MSBAS time series processor**

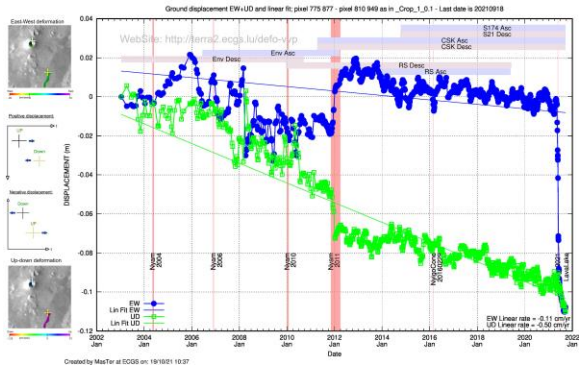
- Incremental and fully automatic
- Combines all available satellites and acquisition geometries
- Produce 2D time series (vertical and EW) and 1D (LOS)
- Provides all types of geocoded products

**See poster by d'Oreye et al.**
**On Thursday 16th, 16-18 CST**

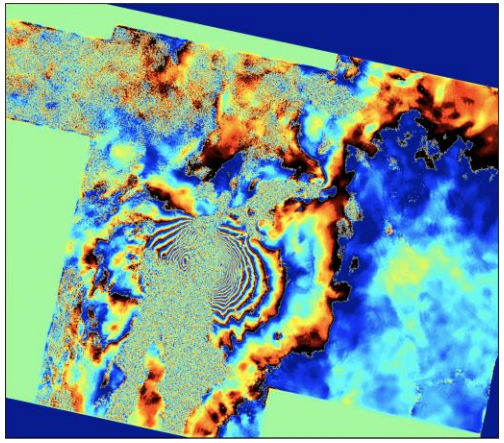
**Examples of MasTer products**



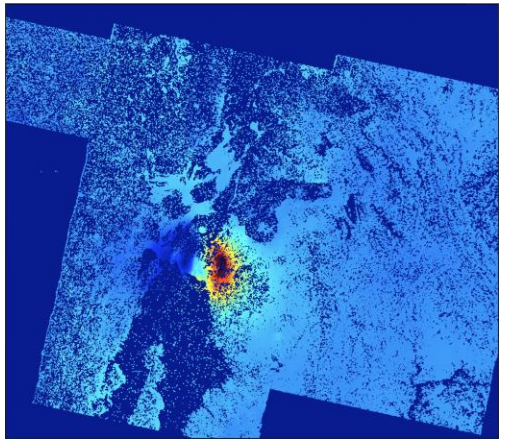

Vertical velocity wrapped on amplitude map



Vertical (Green) and EW (blue) ground deformation time series



S1 Desc filtered interferogram 20210521-20210608



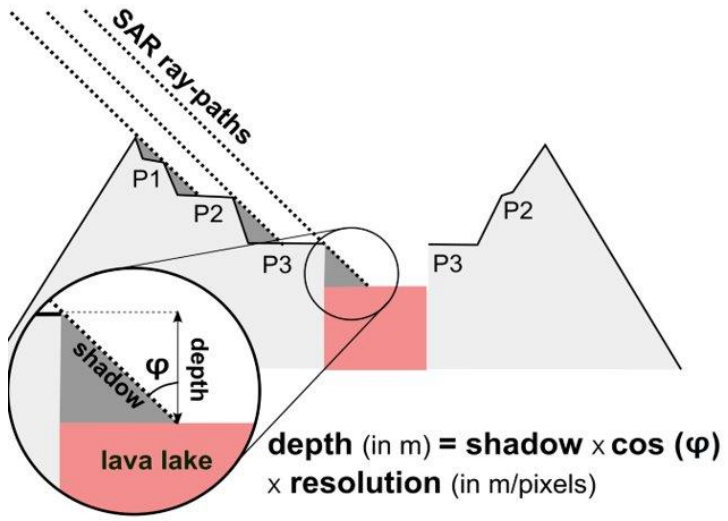
S1 Desc Detrended deformation map 20210521-20210608



(Derauw et al., JSAES, 2020)
(d'Oreye et al., IGARSS, 2021)

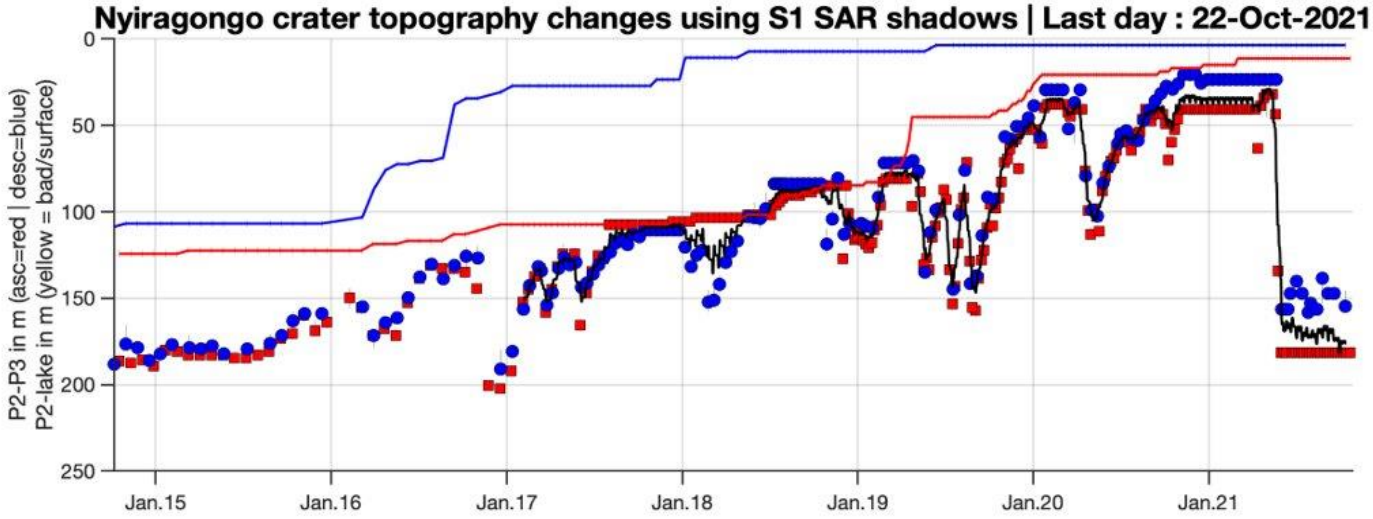
# Automated Tools: SAsha

**Automatic processing of SAR amplitude images for measuring Nyiragongo's lava lake level**


- Basic trigonometry in radar geometry to infer **lava lake level** changes from SAR **shadow**

- Results are available to GVO on a password-protected web page




See poster by Barrière et al.
On Monday 13th, 16-18 CST

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(Oth et al., SRL, 2017)
(Barrière et al., Front., 2018) (Barrière et al., EPSL 2019)

# The 22 May 2021 Nyiragongo eruption

**Around 16h30 UT (18h30 LT)**:

first visual accounts of lava outbursts


*Lava flows from Nyiragongo on 21 May 2021*

*View of the lava lake from Nyiragongo summit on 21 May 2021*


**No warning signs for imminent eruption**



https://georiska.africamuseum.be/en/news/nyiragongo_eruption

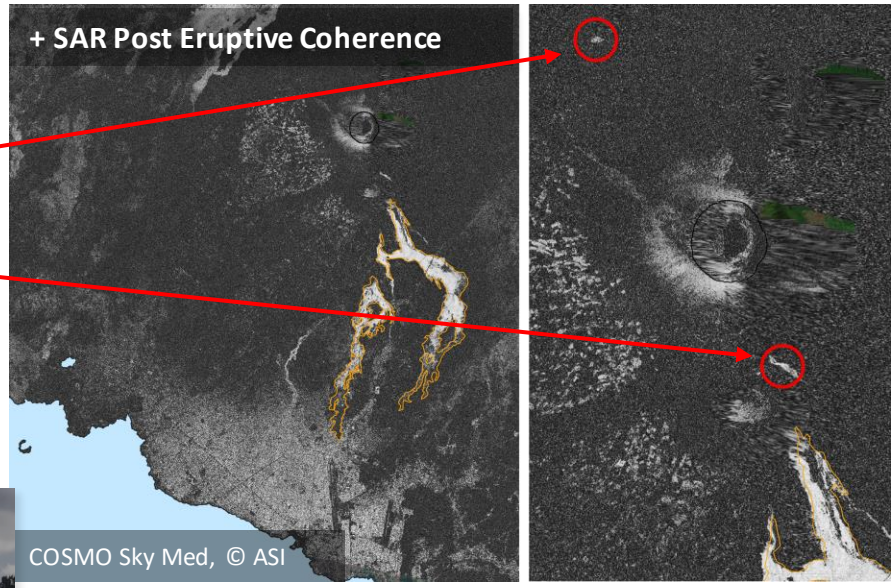
# The 22 May 2021 Nyiragongo eruption

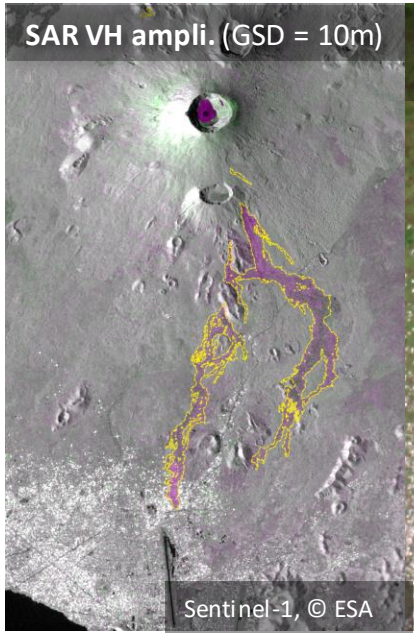
**The eruption lasted about 6 hours**

Lava flows spewed from 4 main fissures (+ 2 small fissures)

Surface covered estimate: 10 km2

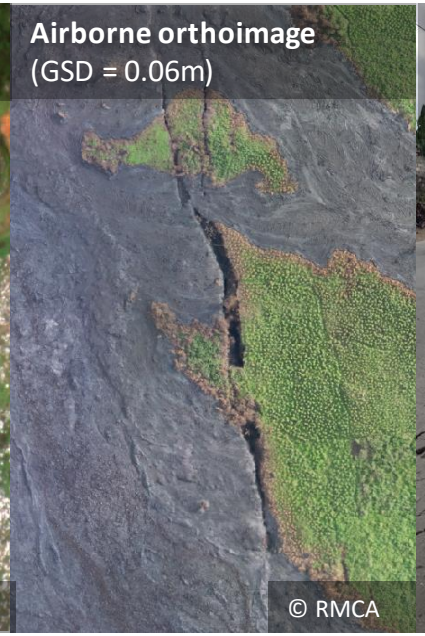
Emitted volume estimate: 10-15 $Mm^3$




$T_{eruption}$ + 3 days


$T_{eruption}$ + 85 days




$T_{eruption}$ + 12 days


Lava Petrology and Geochemistry

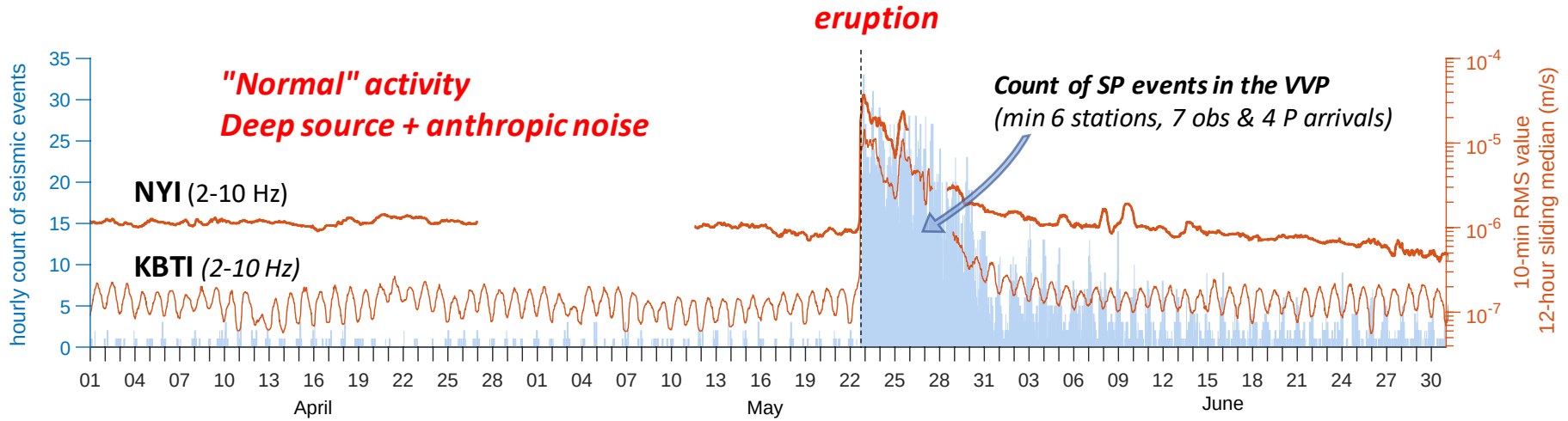
=> **Drainage of the Lava lake system**

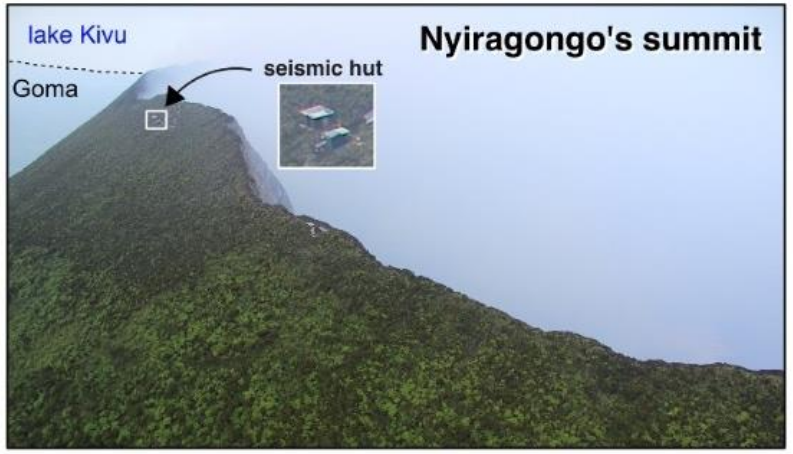
- few millimetre-scale bubbles
- nepheline crystals

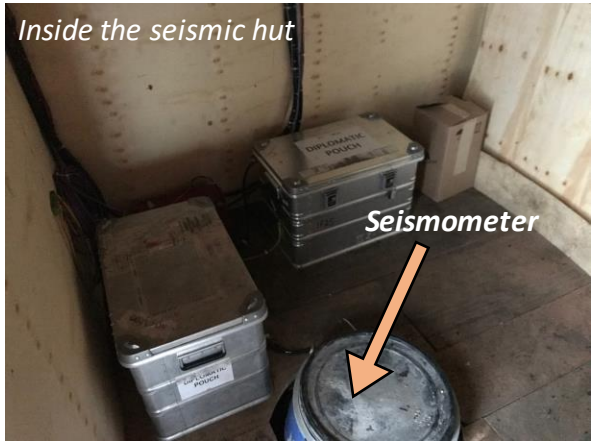
**See also talk by Smets et al. On Wenesday 15th, 07:50-07:55 CST**

# No evident precursors

**KivuSNet (seismic & infrasound):**
With the available network, no precursory seismicity patterns could have been associated with an impending eruption in a prospective forecasting framework

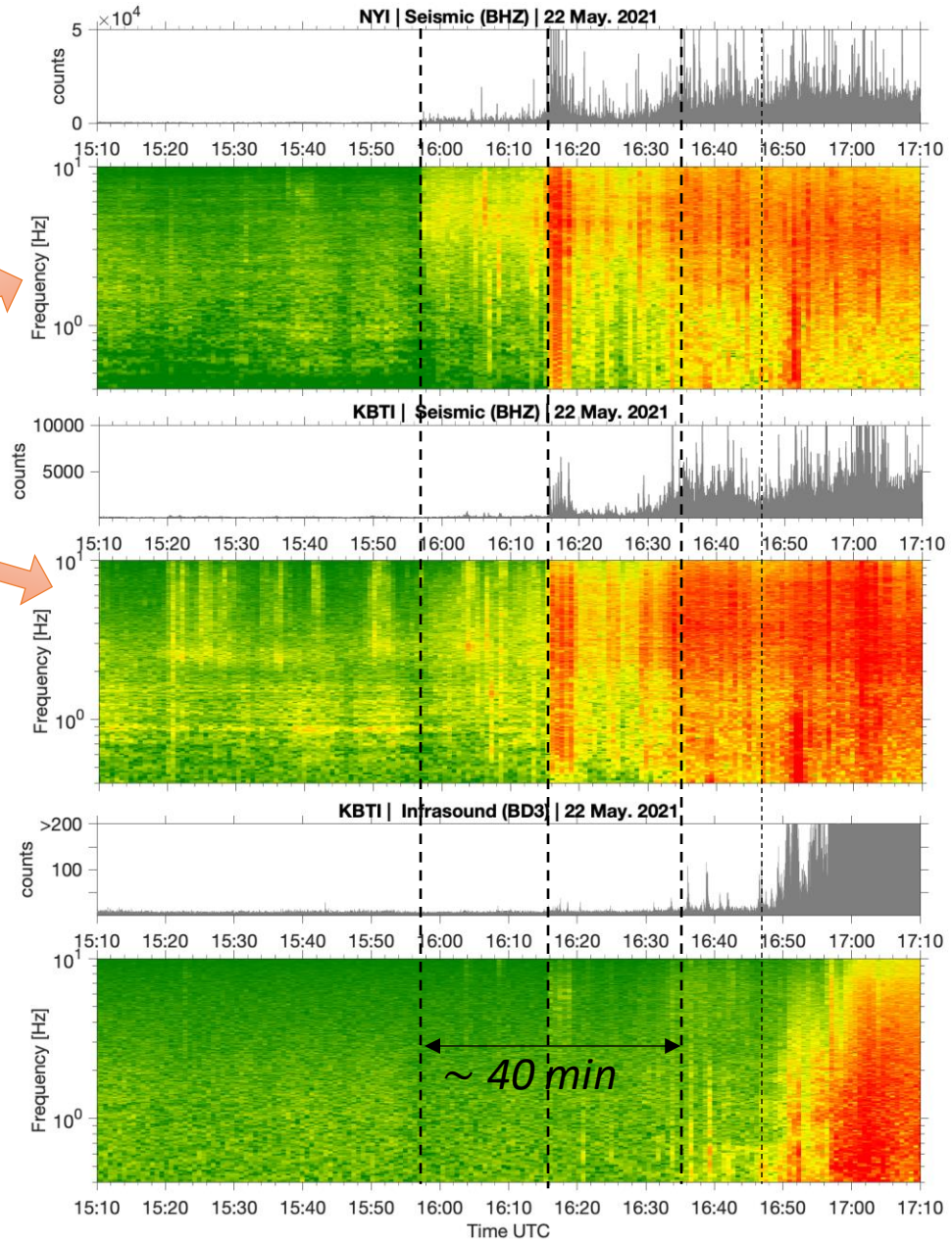






https://georiska.africamuseum.be/en/news/nyiragongo_eruption

# No evident precursors


**Zoom in 22 May - 15:10 to 17:10 UTC**

First seismic signals at station NYI at ~15:57 UTC (17:57 LT)

Clear seismic events at KBTI (& other stations) at ~16:15 UTC (18:15 LT)

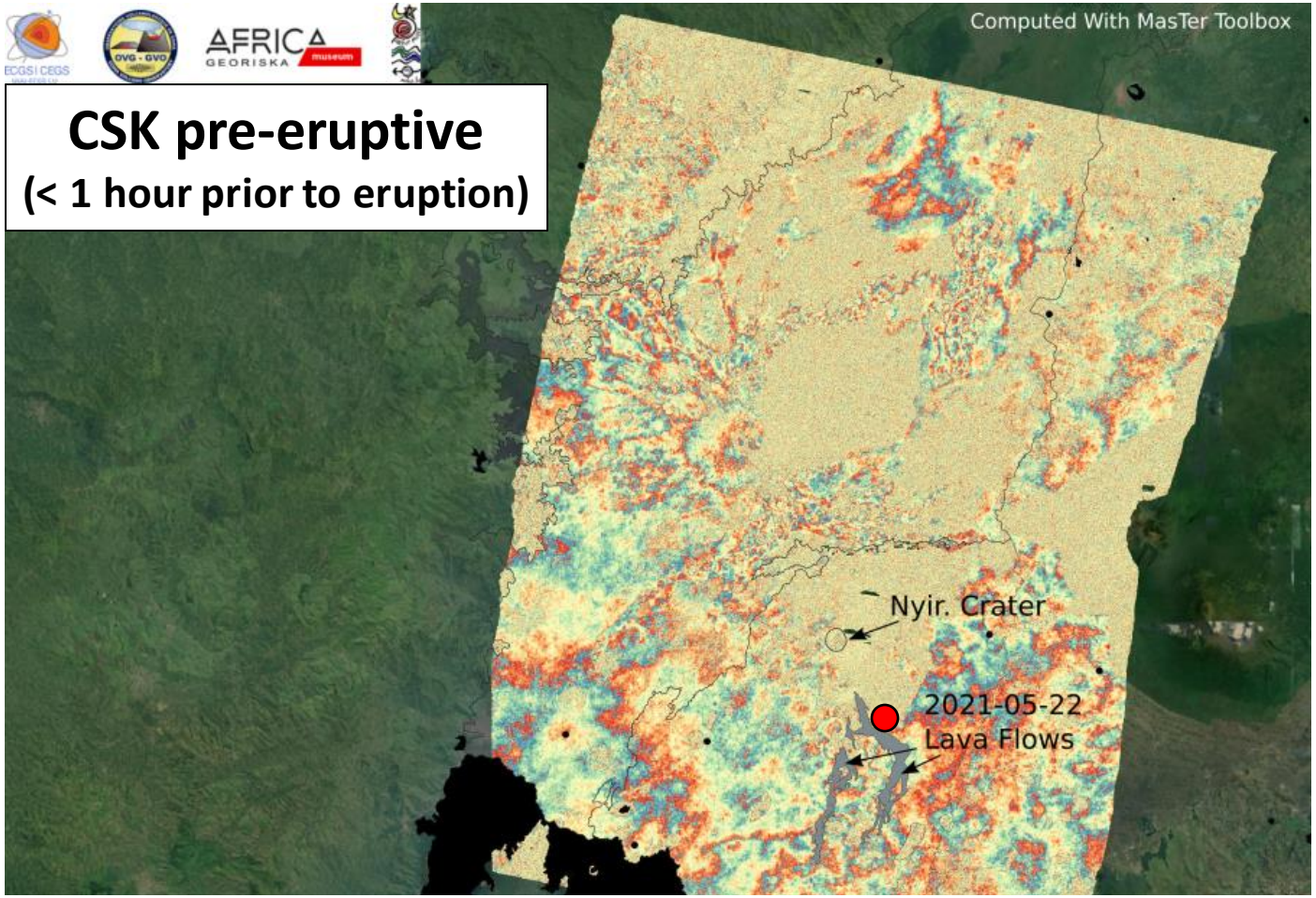
Clear acoustic (infrasound) signals at KBTI starts with delay of ~20 min at ~16:35 UTC (18:35 LT), roughly coinciding with first visual accounts of lava outbursts

⇒ **(Very) short distance between magma source and surface**

⇒ **(Very) dense instrumentation of edifice might at best have provided some (very) short-term warning signs**

# No Precursory Deformation

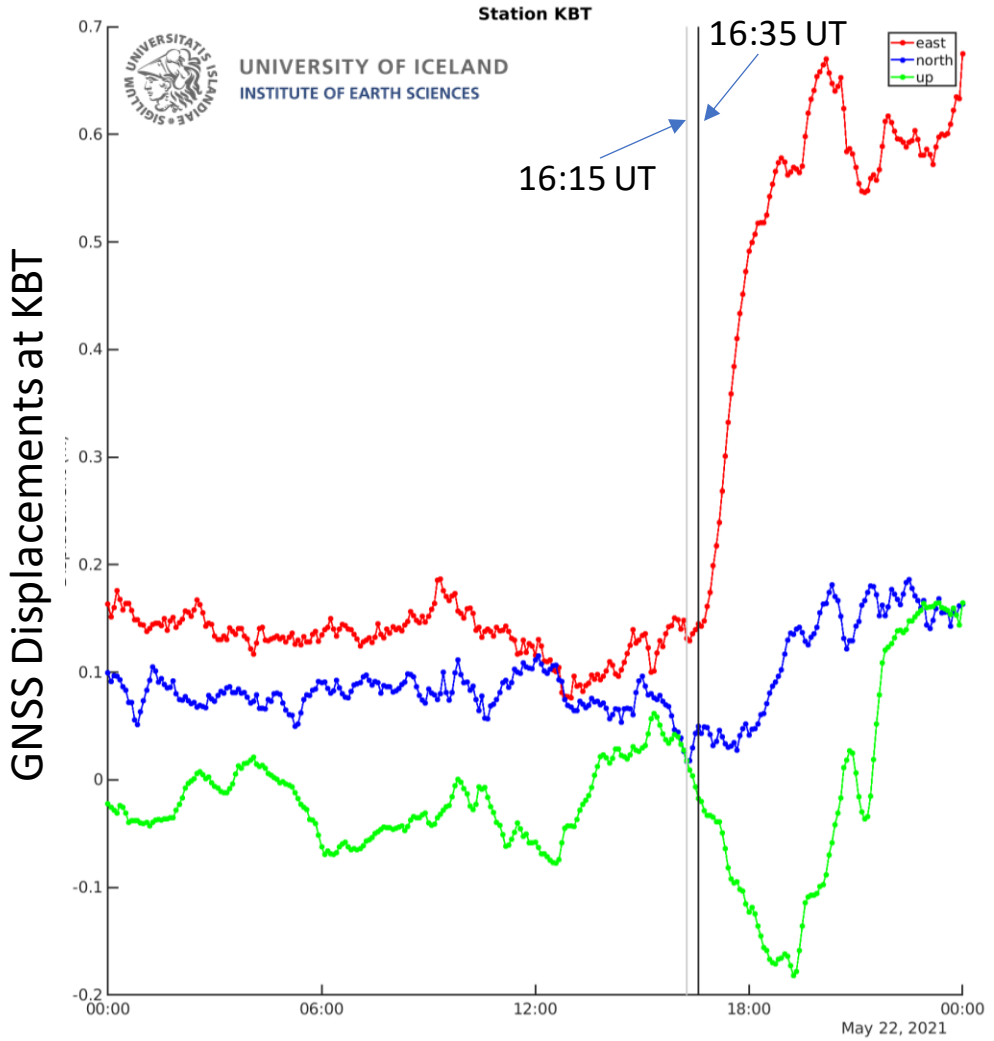
**MasTer (InSAR):** in pre-eruptive interferogram




COSMO Sky Med Desc. ©ASI
2021-05-21 15:37 2021-05-22 15:37

1 fringe = 1.5cm deformation in LOS

**KivuGNet (GNSS):** at station closest to Nyiragongo

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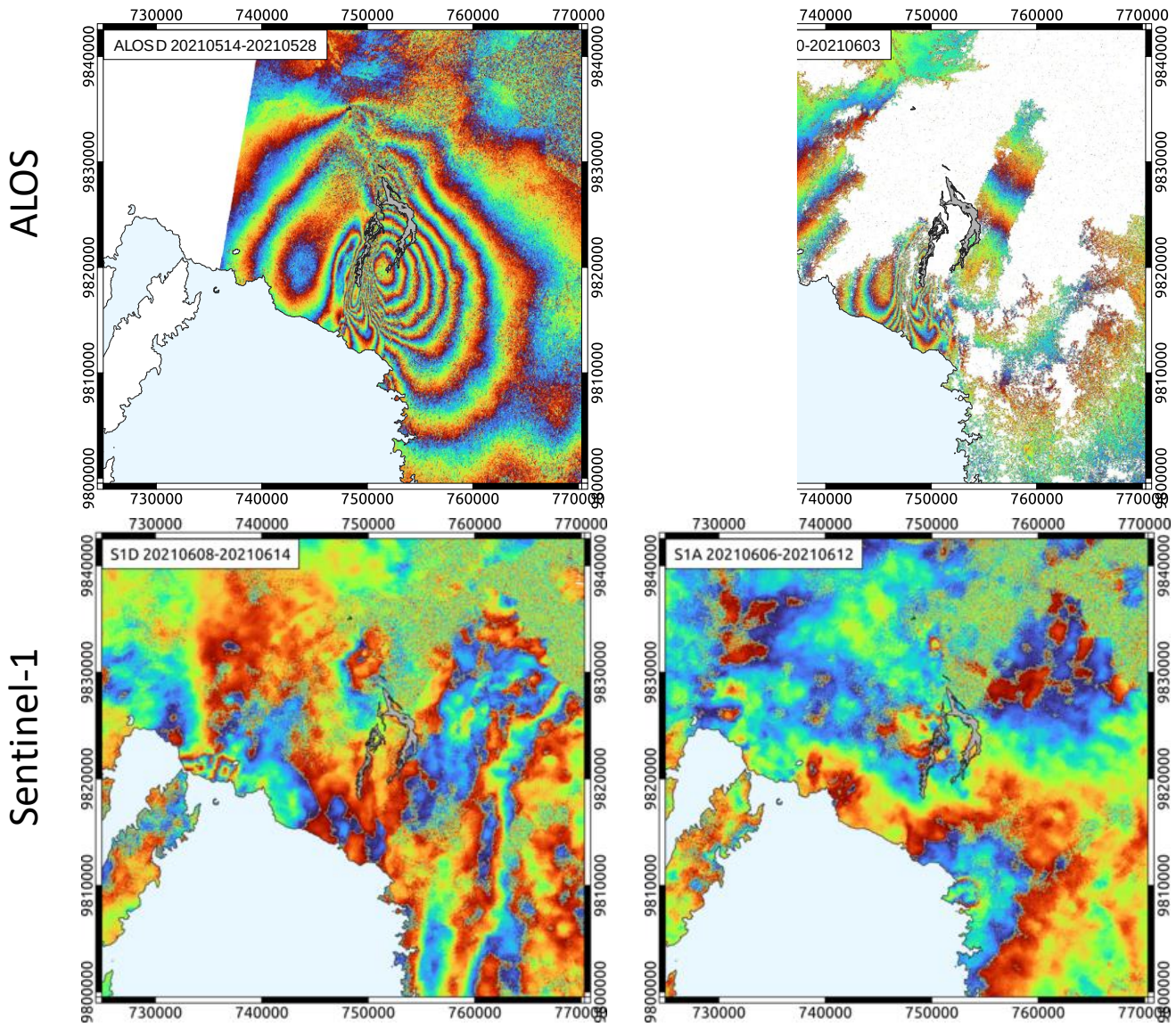
# Tracking and interpretatio

**Co-eruptive deformation (interferograms)**

- 3 lobes-pattern : EW opening + graben subsidence
- Opening of around 1.5 m in Goma
- Dyke progression (“textbook-like”)
- Graben faulting still on-going after June 2nd






https://georiska.africamuseum.be/en/news/nyiragongo_eruption

# Tracking and interpretation

## Pre-eruptive seismicity

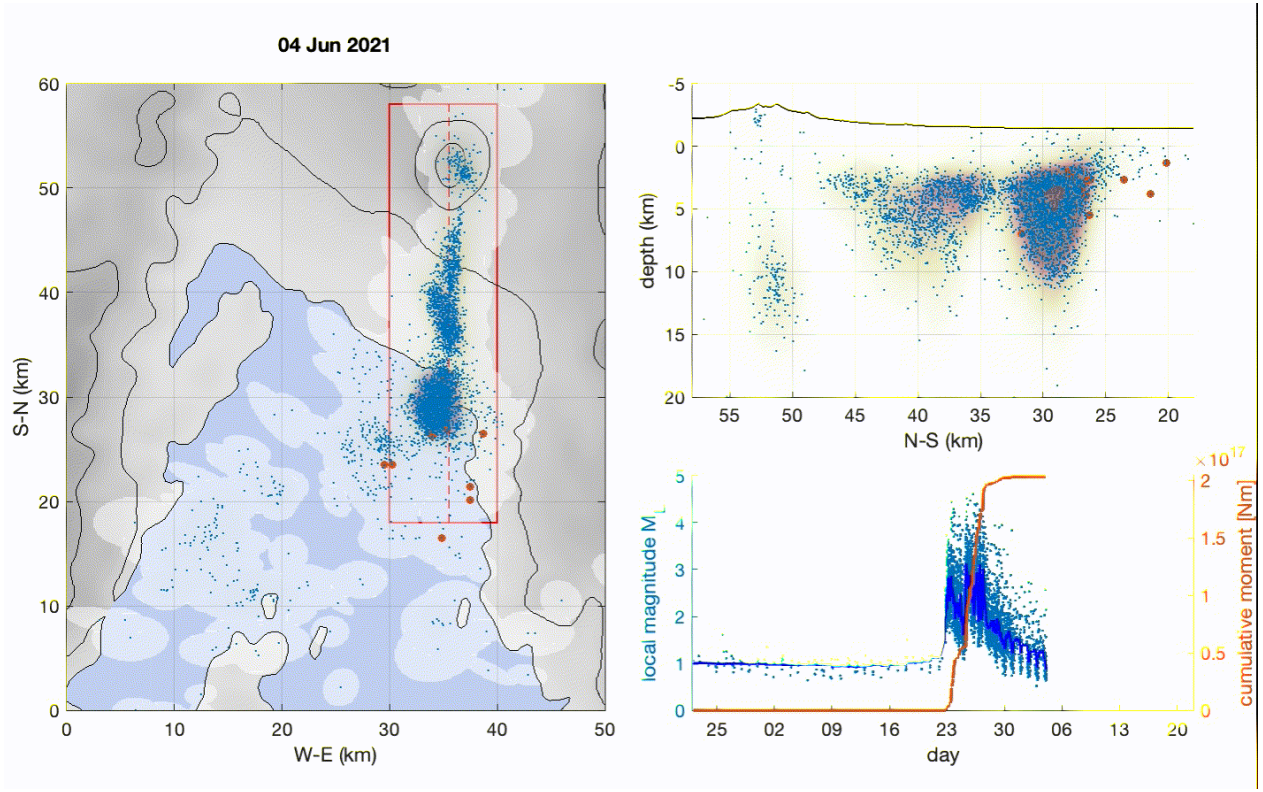
- **Deep** repetitive seismic source at 10 – 15 km (feeding system)
- **Tectonic** background seismicity in and around Lake Kivu (→ rift)
- Diurnal variations due to **anthropogenic noise**

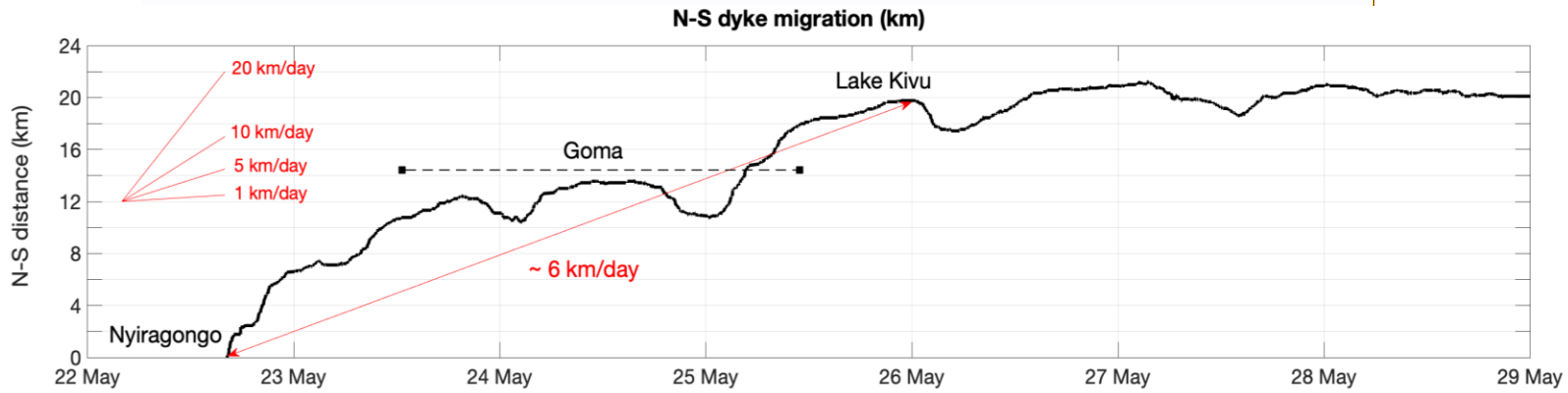
## Volcanic crisis

Seismic swarm **migrating north to south,** evidencing dyke progression

Very **shallow** seismicity, **strongly felt** in cities of Goma and Gisenyi

Dyke **progression in bursts**, velocities up to ~20 km/day



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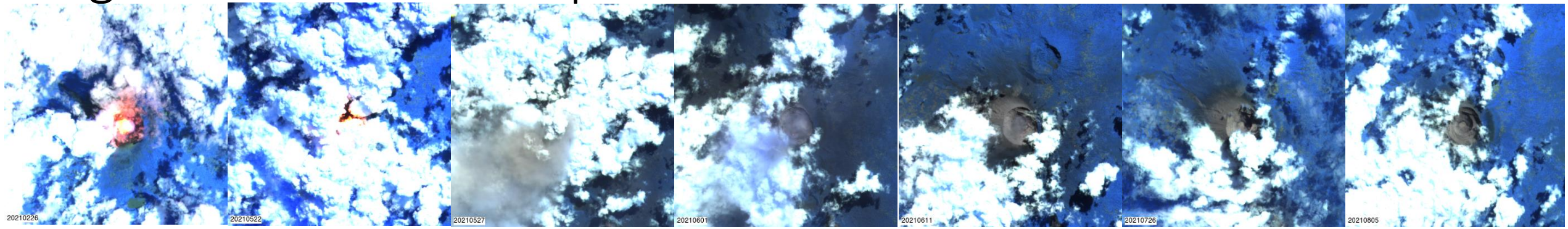
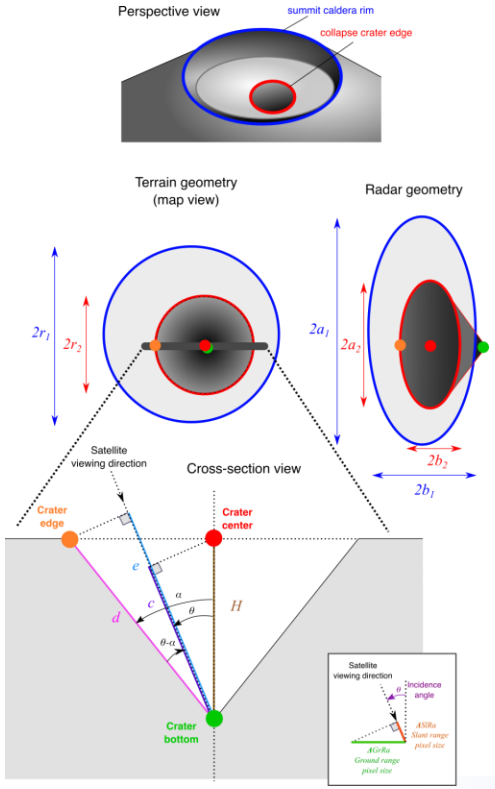
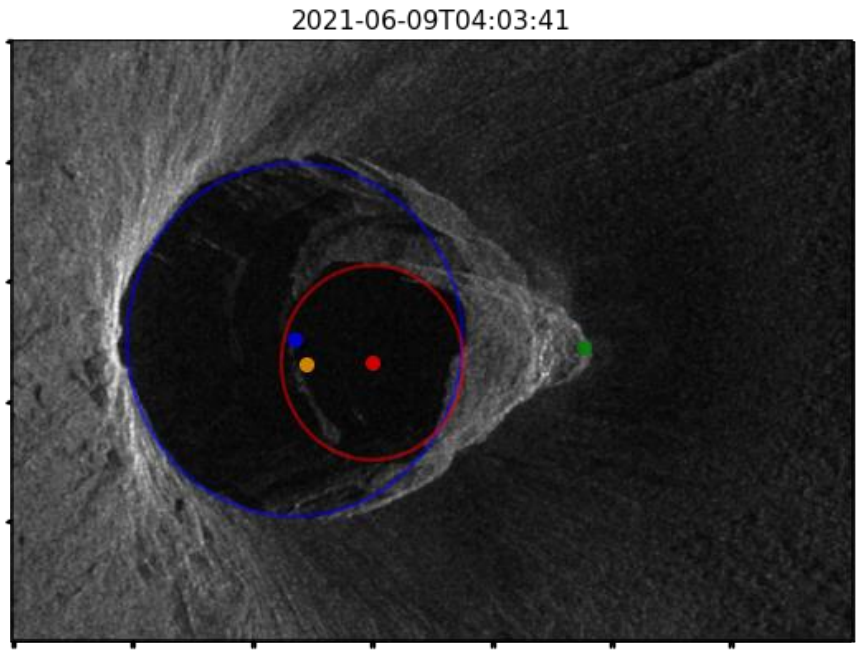
# Progressive Crater Collapse

Sentinel-2 Multi-spectral

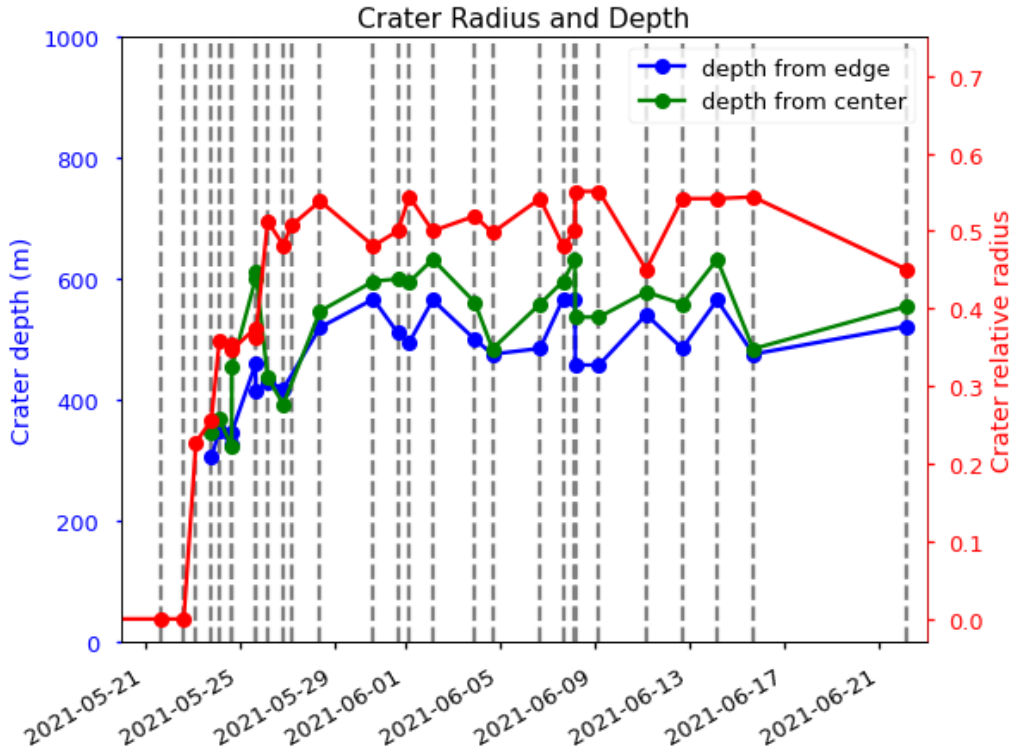



SAR amplitude

COSMO Sky Med

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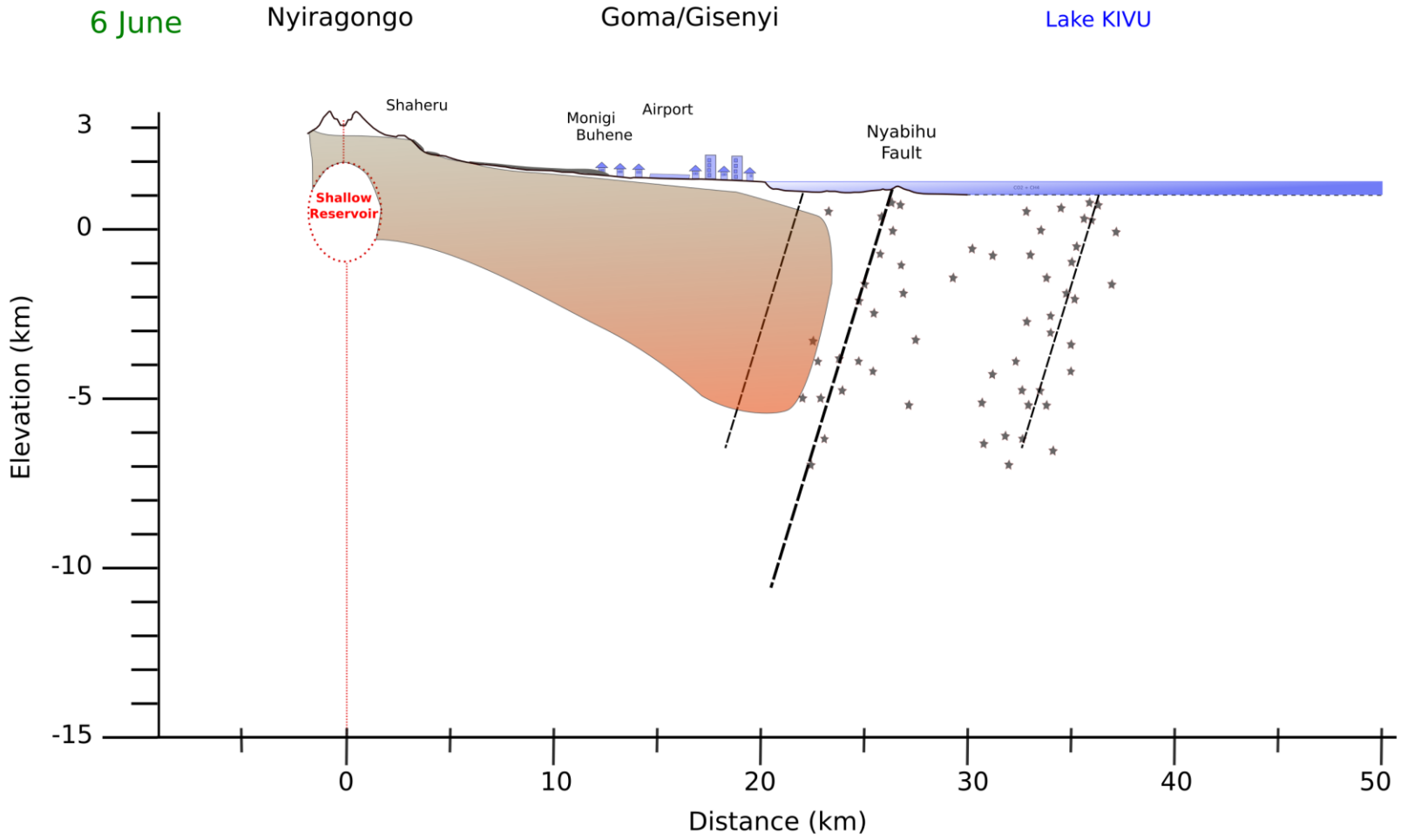
# Interpretation and Conclusions

First modelling results show a 240Mm$^3$ dyke progressing at **shallow depth** roughly in north-south direction

**Progression unpredictable** (up or down, lateral changes in direction, obstacles, Nyabihu fault)

**Very significant associated risks** (lava outbursts directly within Goma or Gisenyi, phreato-magmatic eruption, limnic eruption of Lake Kivu)

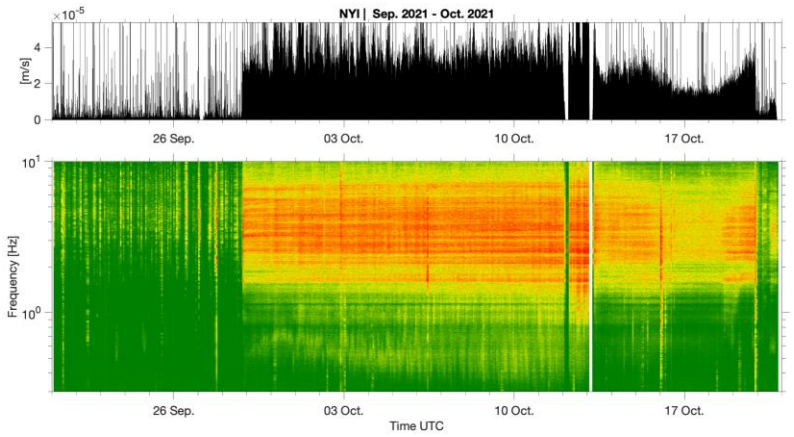
**(Re-)Activation of tectonic structures** in/around Lake Kivu

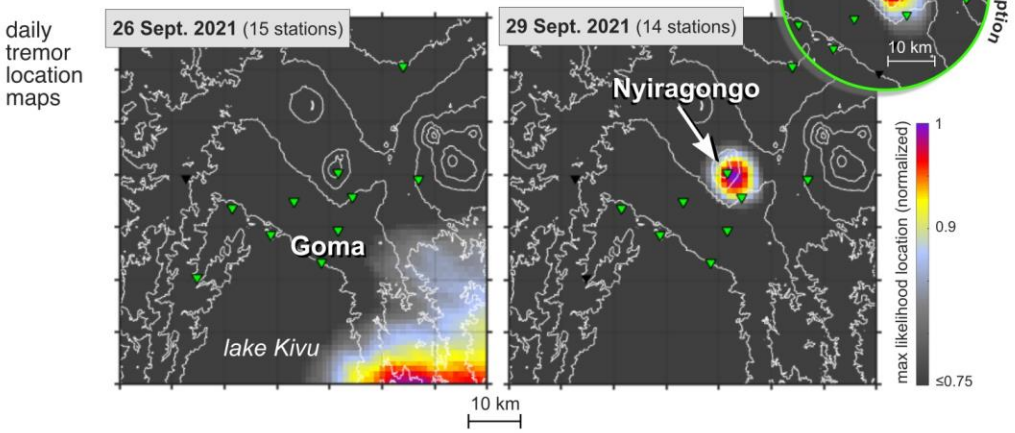


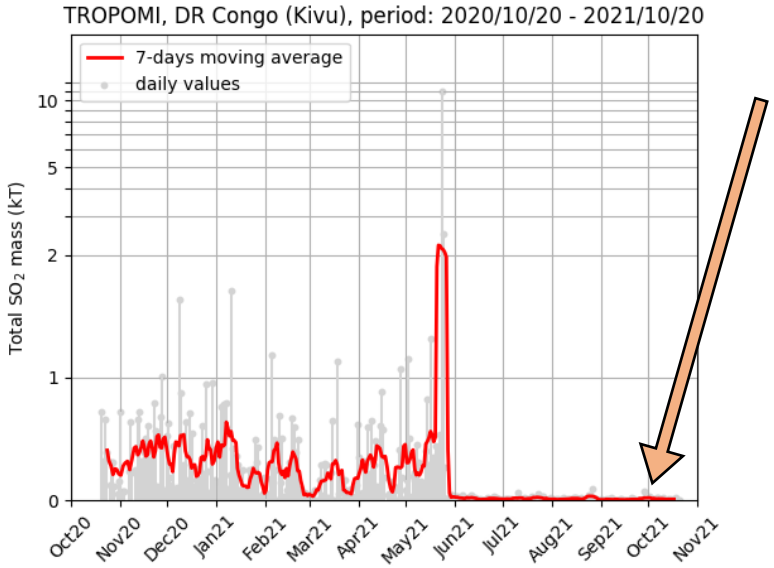

**Schematic interpretation of the 2021 Nyiragongo volcanic crisis**

# What's next?

**Summit activity is coming back**;
similar seismic tremor signature
still intermittent at the current stage

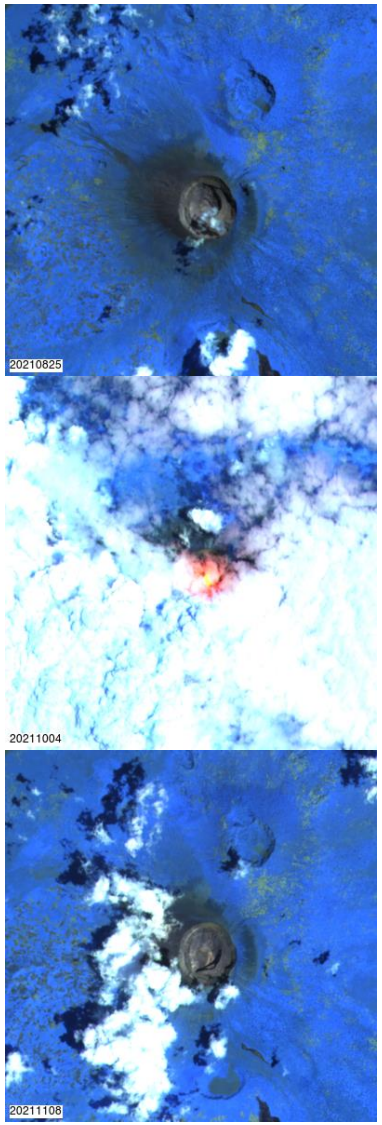



Still very low $SO_2$ emission

Sentinel-2 images
(bands 12 11 8a)
25 August
04 October
08 November

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Additional information on: https://georiska.africamuseum.be/ & https://www.virunga-volcanoes.org/