



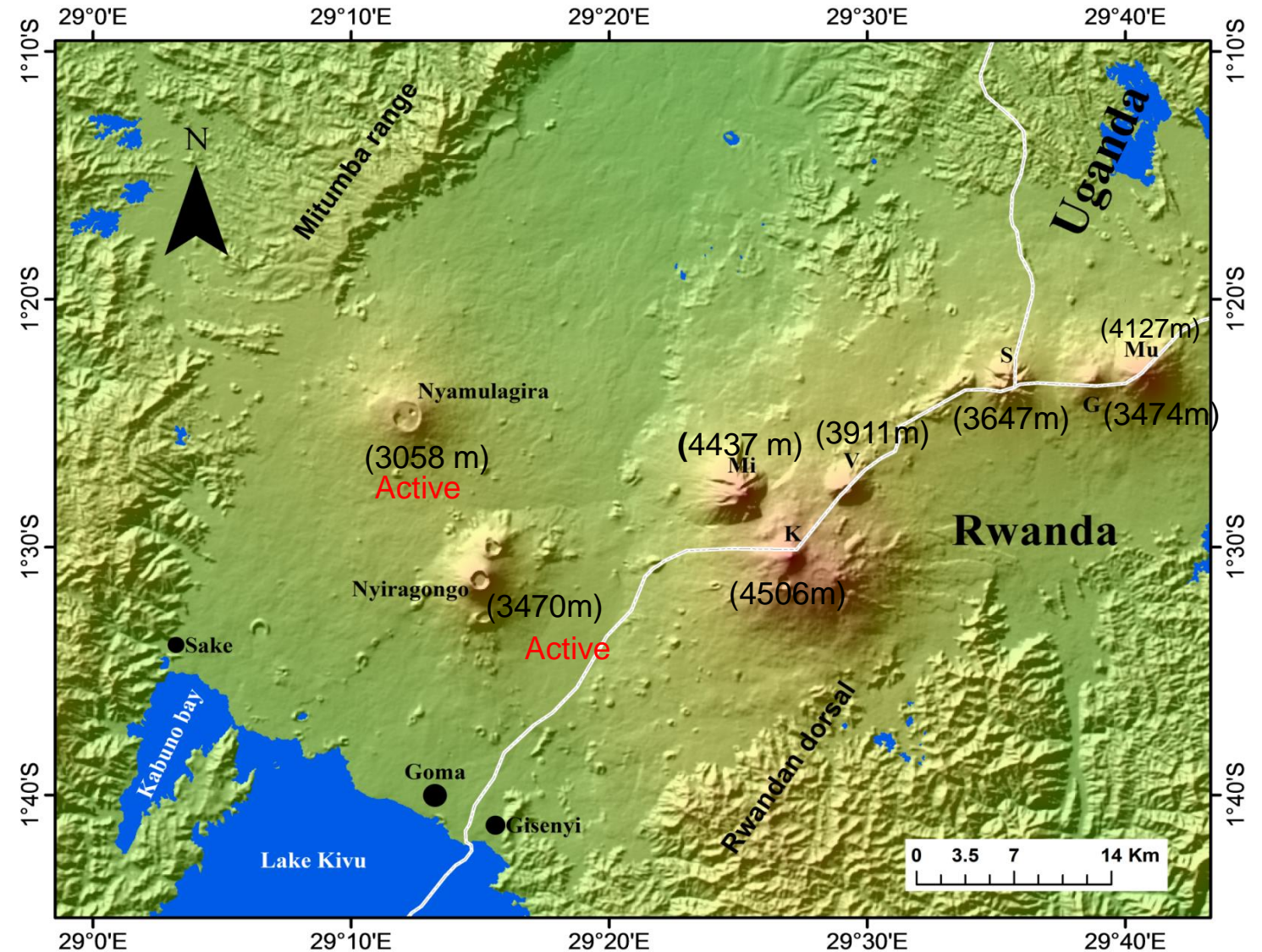
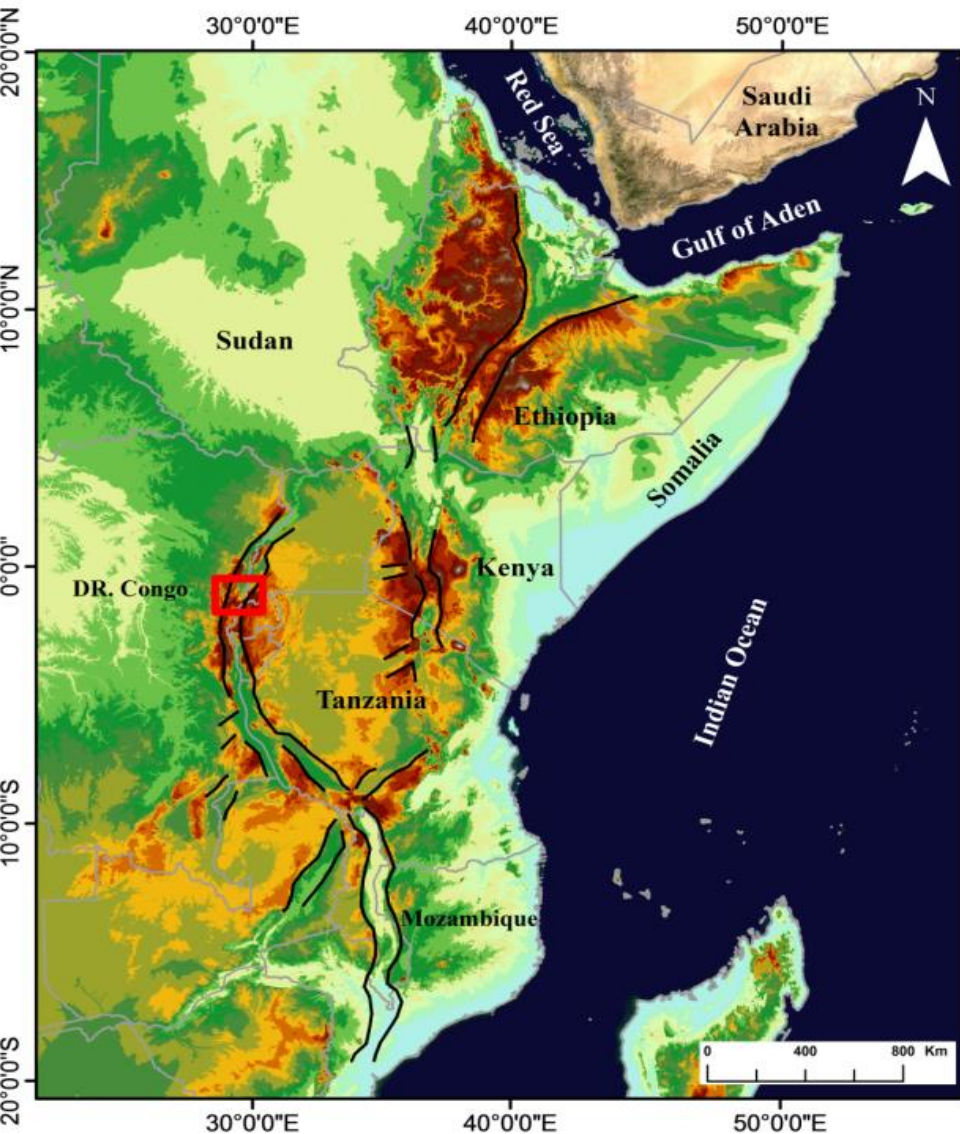
Role of Supersite initiative in improving volcano research, volcano monitoring and hazards in low income countries: the case of Virunga Volcanoes Supersite in DR Congo, East Africa

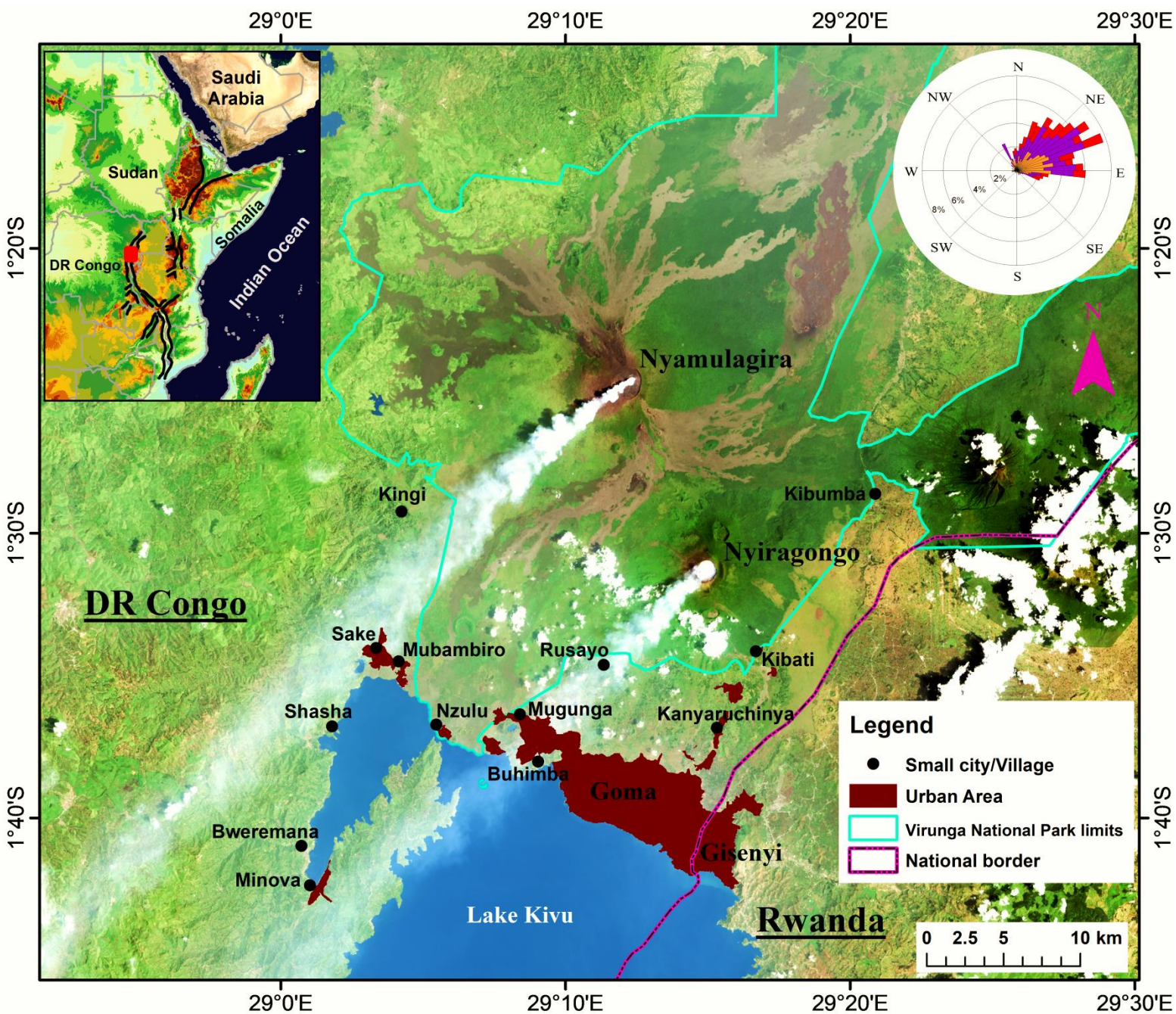
Charles Balagizi
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**1st EPOS International Conference:
EPOS Meets Africa and Latin America
Sal Island (Cape Verde) , July 11-13, 2022**

1. The Virunga Supersite : context

The Virunga Volcanic Province is located in the western branch of the East African Rift





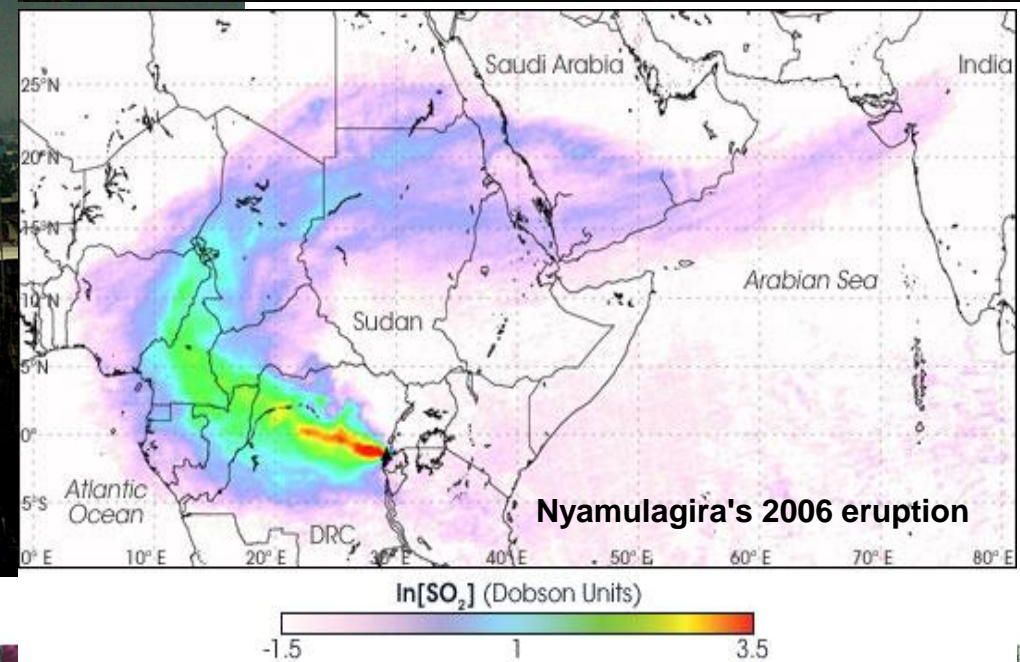
Several natural hazards are encountered in the Virunga and Lake Kivu basin include:

- (i) Volcanic hazards:** i.e. lava flows, volcanic gases and ash, acid rain
- (ii) Earthquake hazard,** as a tectonically active region
- (iii) Landslides,** as a mountainous et tropical region with earthquakes
- (iv) Reduced rain and surface water quality** by the volcanism (e.g. high fluoride content),
- (v) Mazuku or soil-dry gas vents,** in and around Goma
- (vi) CO₂ & CH₄ dissolved in Lake Kivu** which may potentially erupts, such as what happened at the Cameroonain Monoun and Nyos lakes in 1984 and 1986

Volcanic gas and ash hazards



Nyi



**Rainwater represents an important water resource, but is contaminated by the volcanic plume:
The quality of water is reduced (e.g. low pH) and the acid rain impacts on infrastructures**

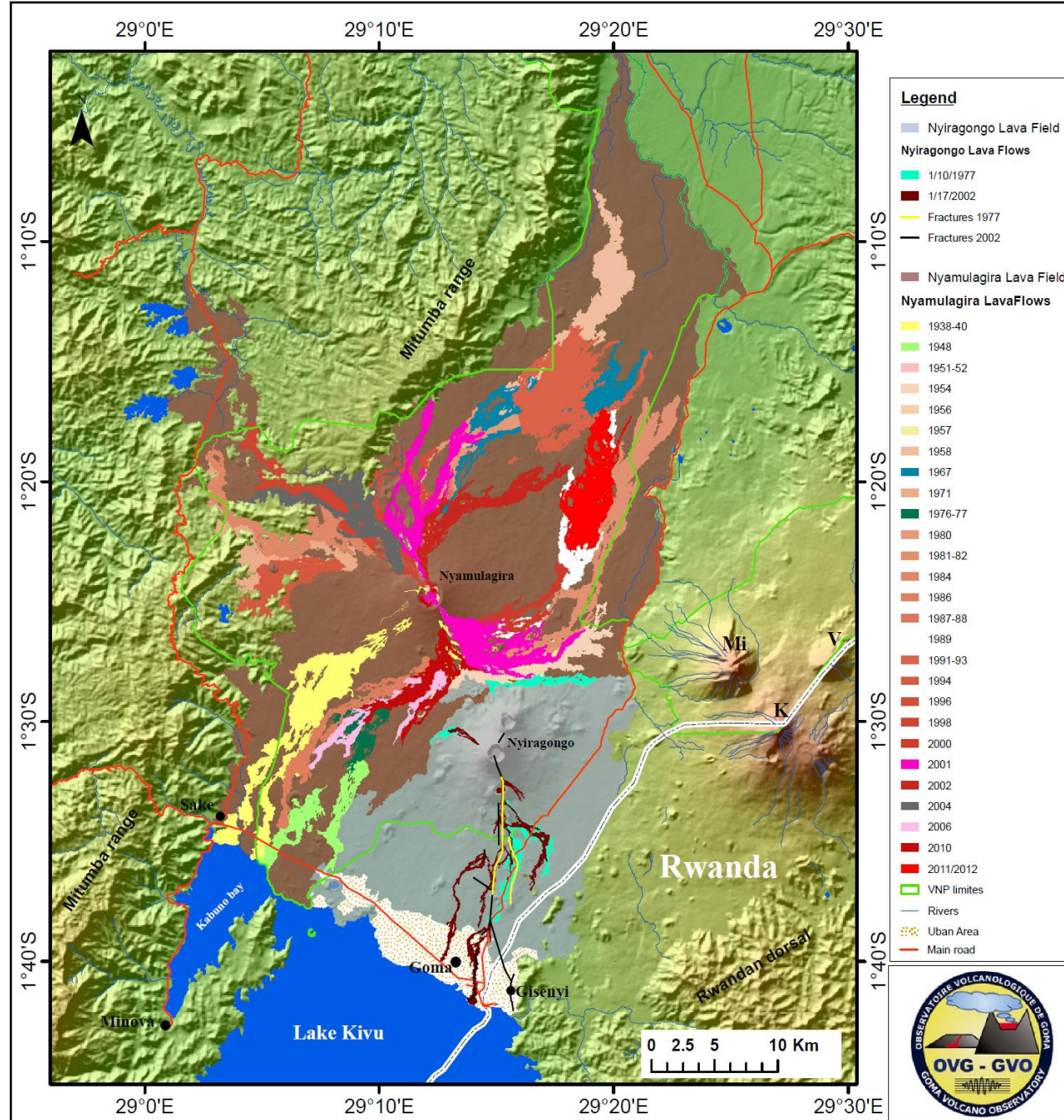


Example of water pollution impacts on human health (dental fluorosis)

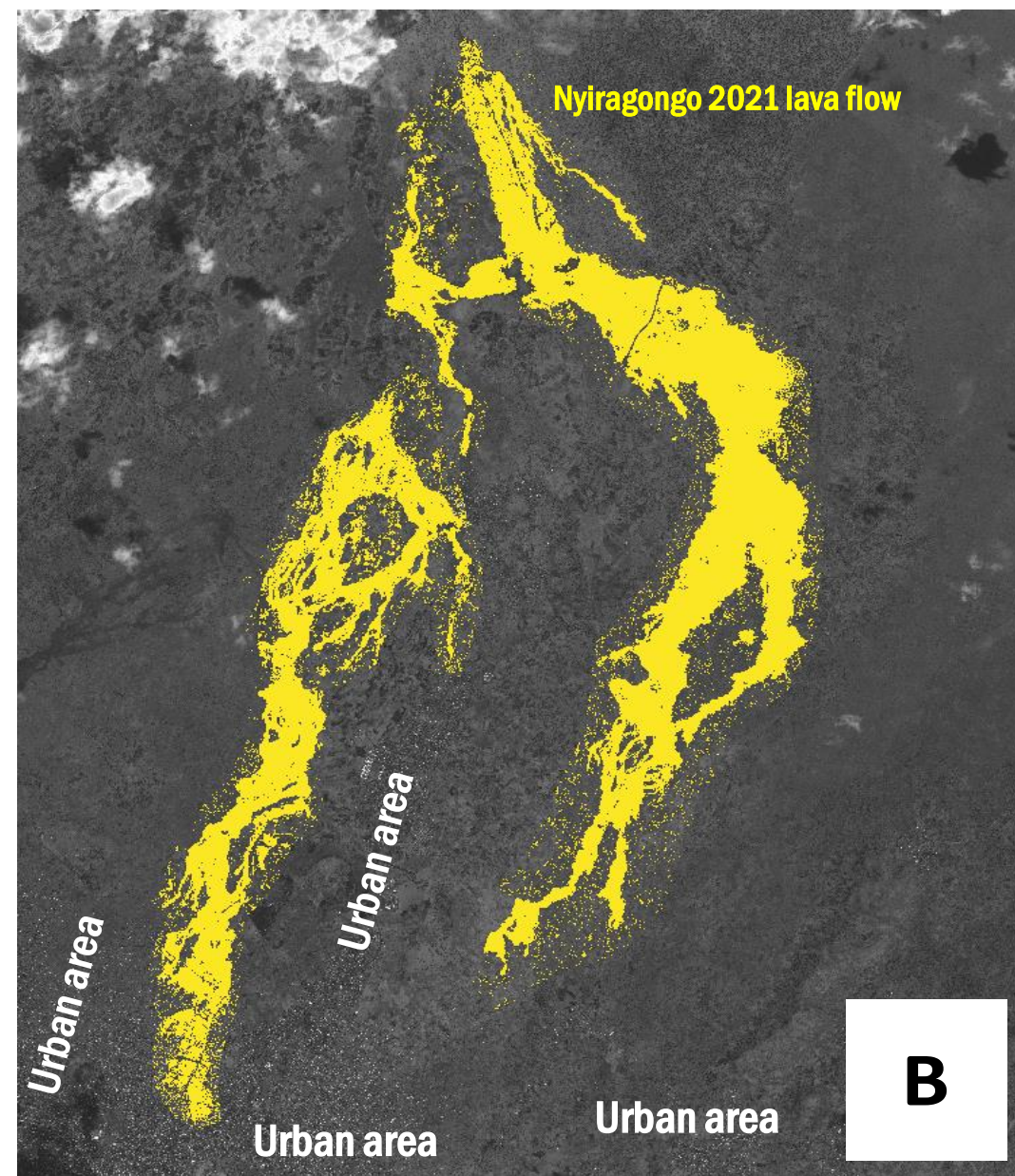


1938-2020 :

- at least 40 eruptions of Nyamulagira and
- 2 eruptions of Nyiragongo



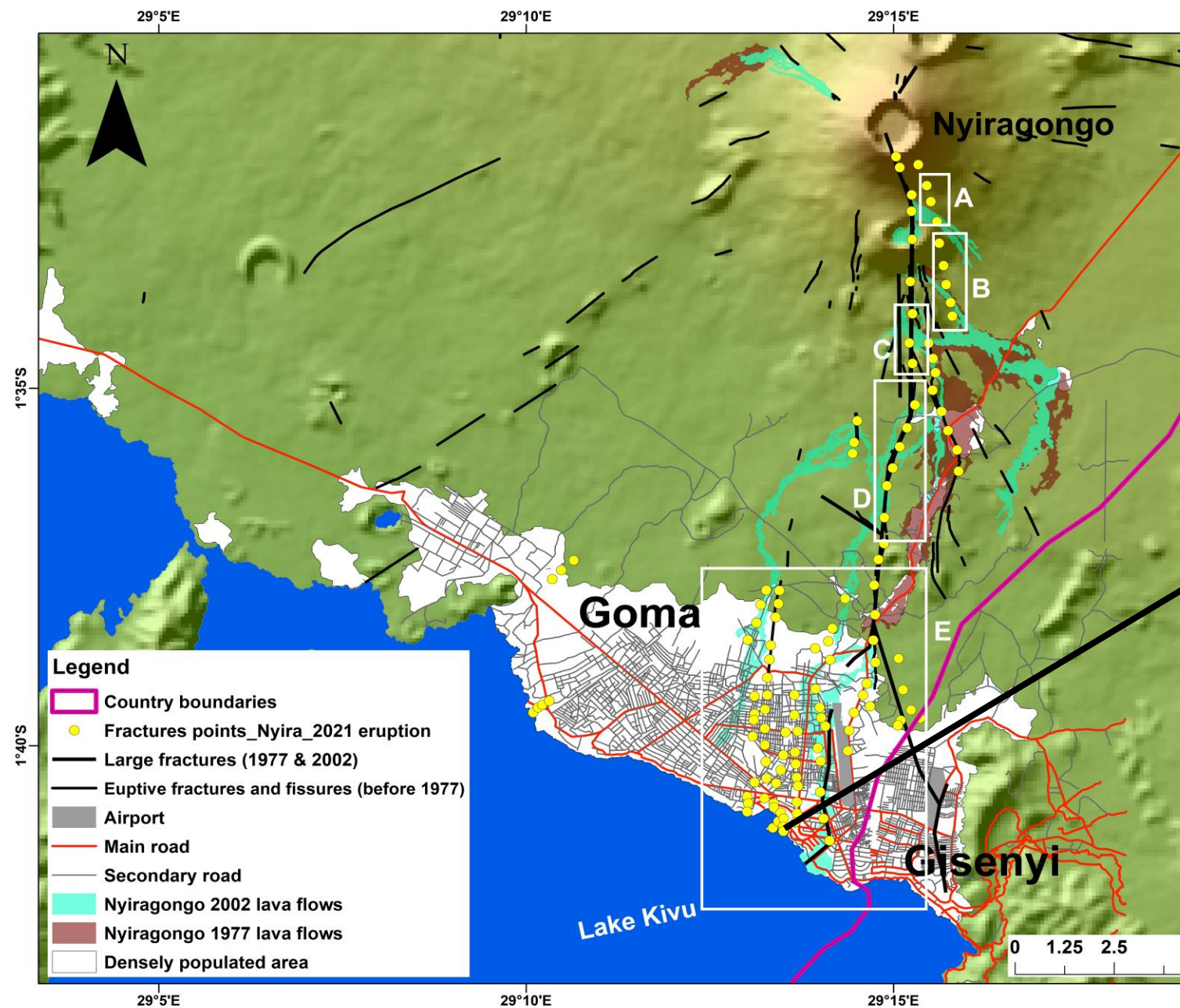
Lava flow Hazards

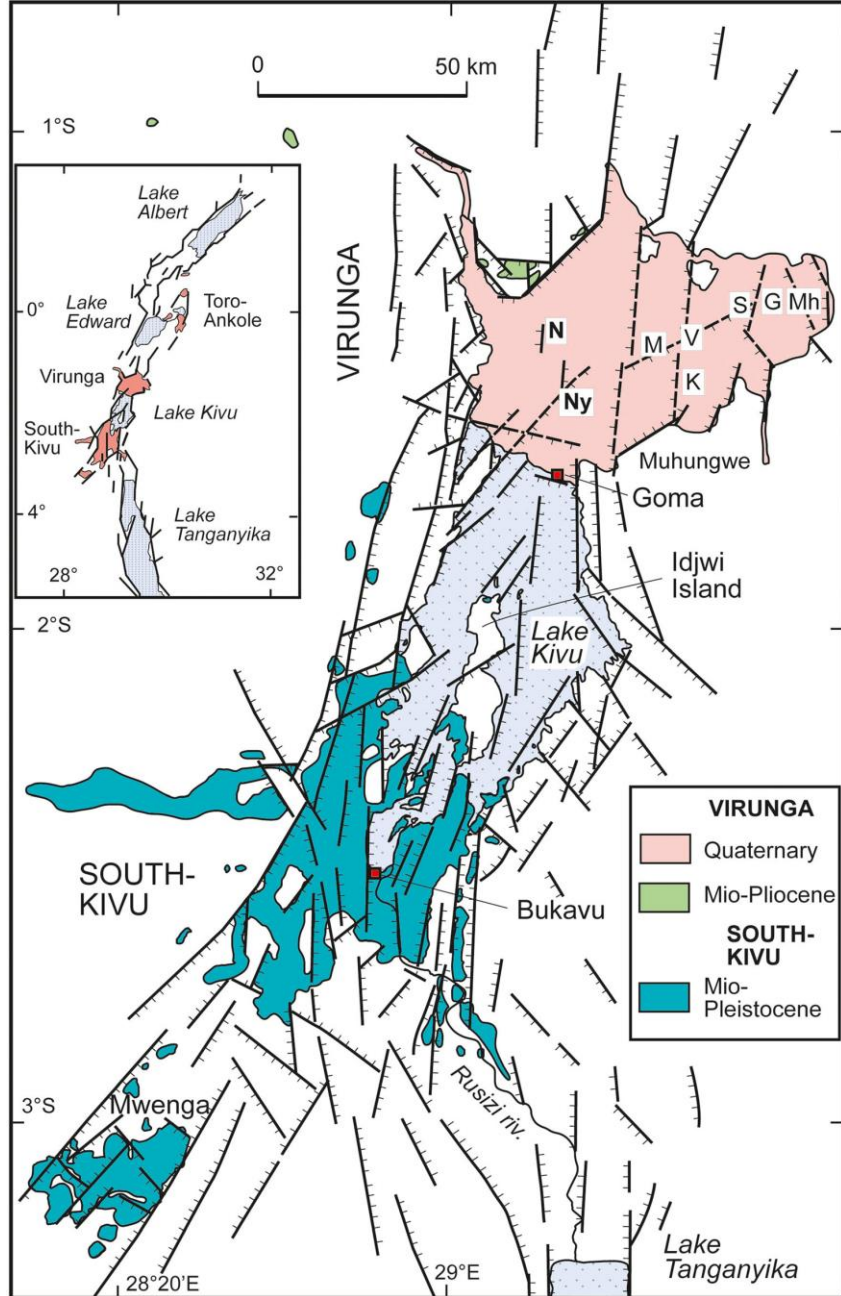


Nyiragongo 2021 lava flow



Map of fractures due to the Nyiragongo eruption 2021

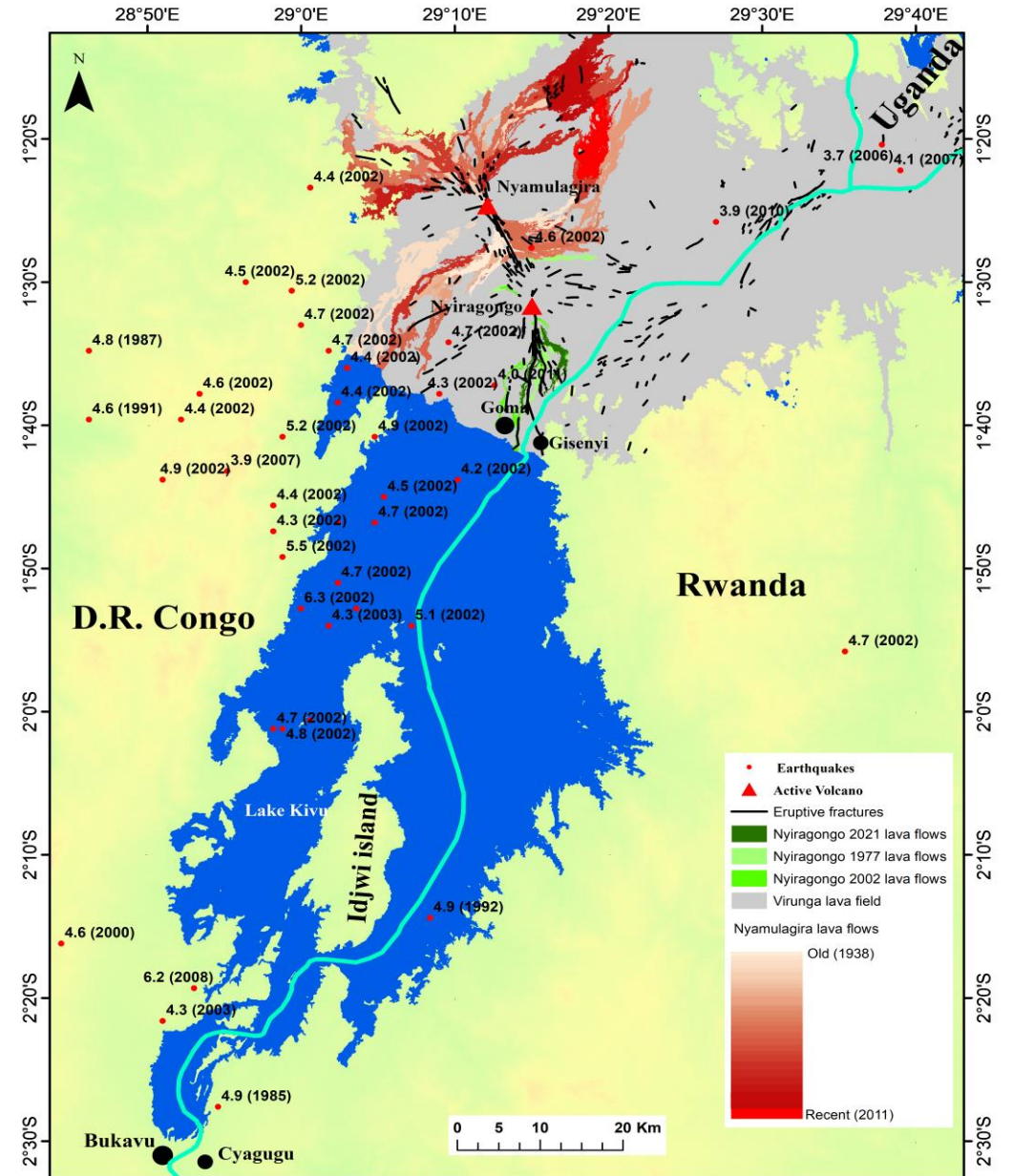




EPoS Tectonic map of the Virunga Lake Kivu basin Pouclet et al. (2016)

Earthquake and landslide hazards

— faults



Main earthquakes (Mw ≥ 3.5) in the Virunga and Lake Kivu Basin (



Congo

2008.02.11



Congo

2008.02.07



Rwanda

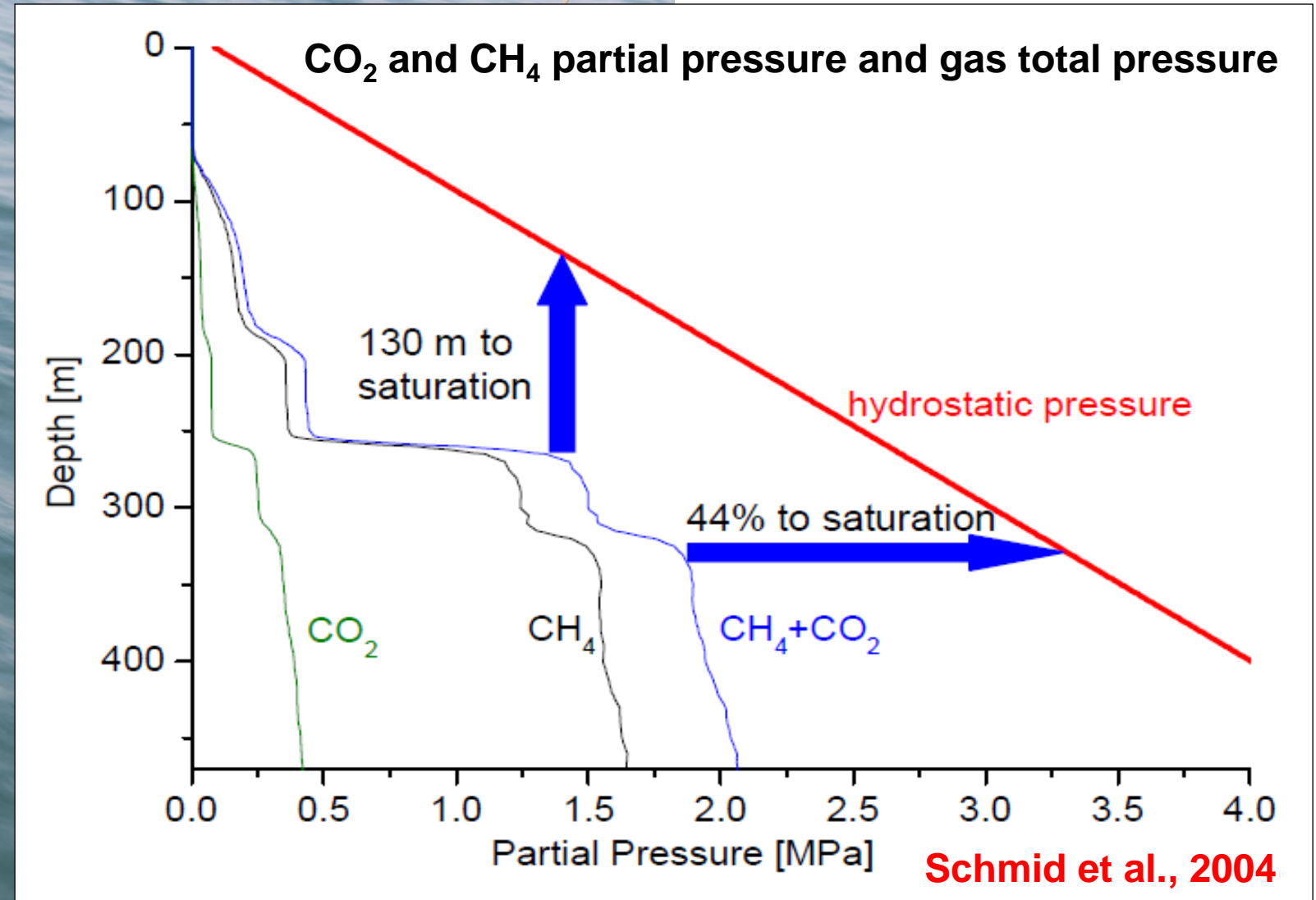
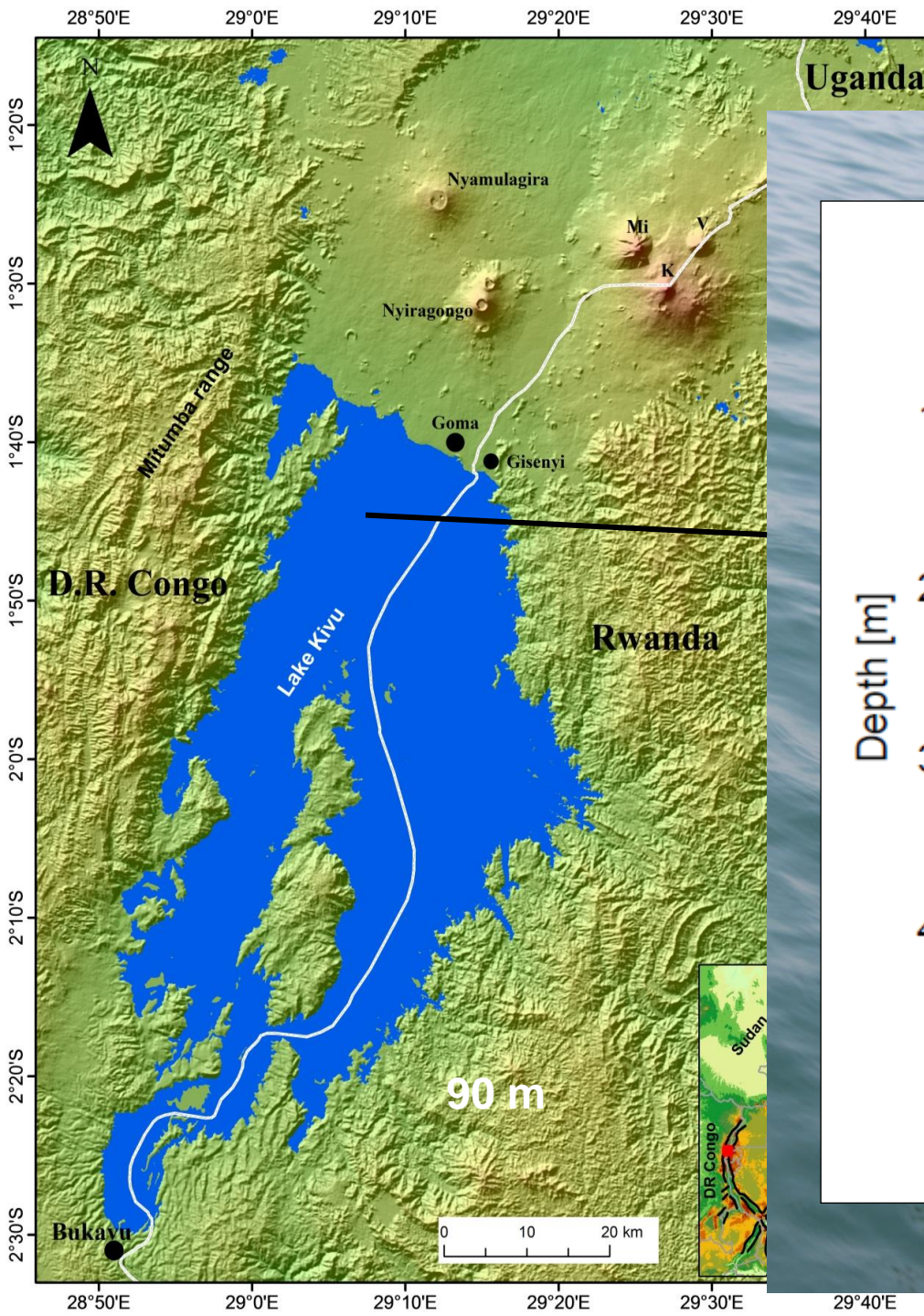
2008.02.19



Mud flow in Kibumba in 2010 killed 19 people; 47 others were missing



Lake Kivu : Hazards related to dissolved gases

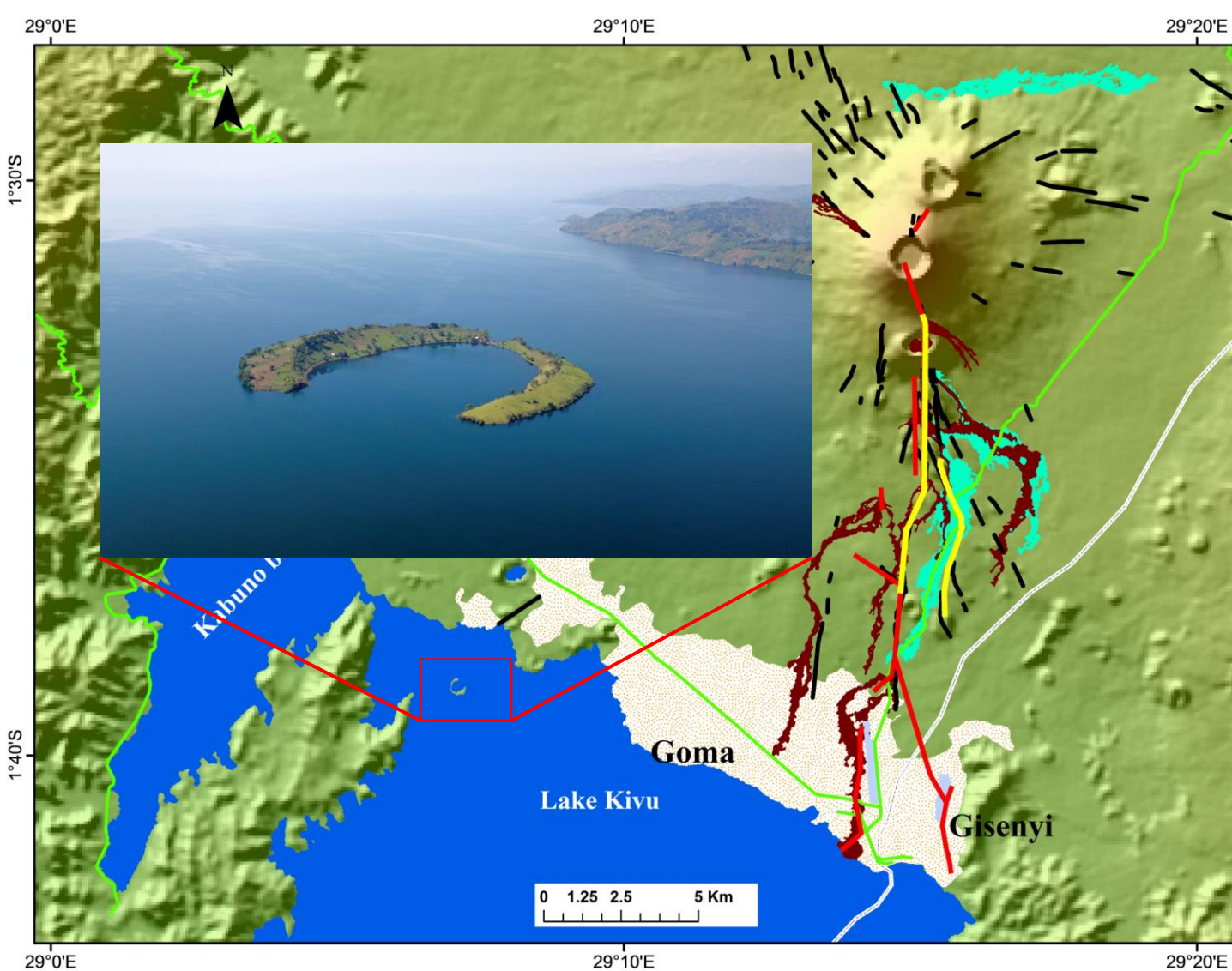


Risk for limnic eruption

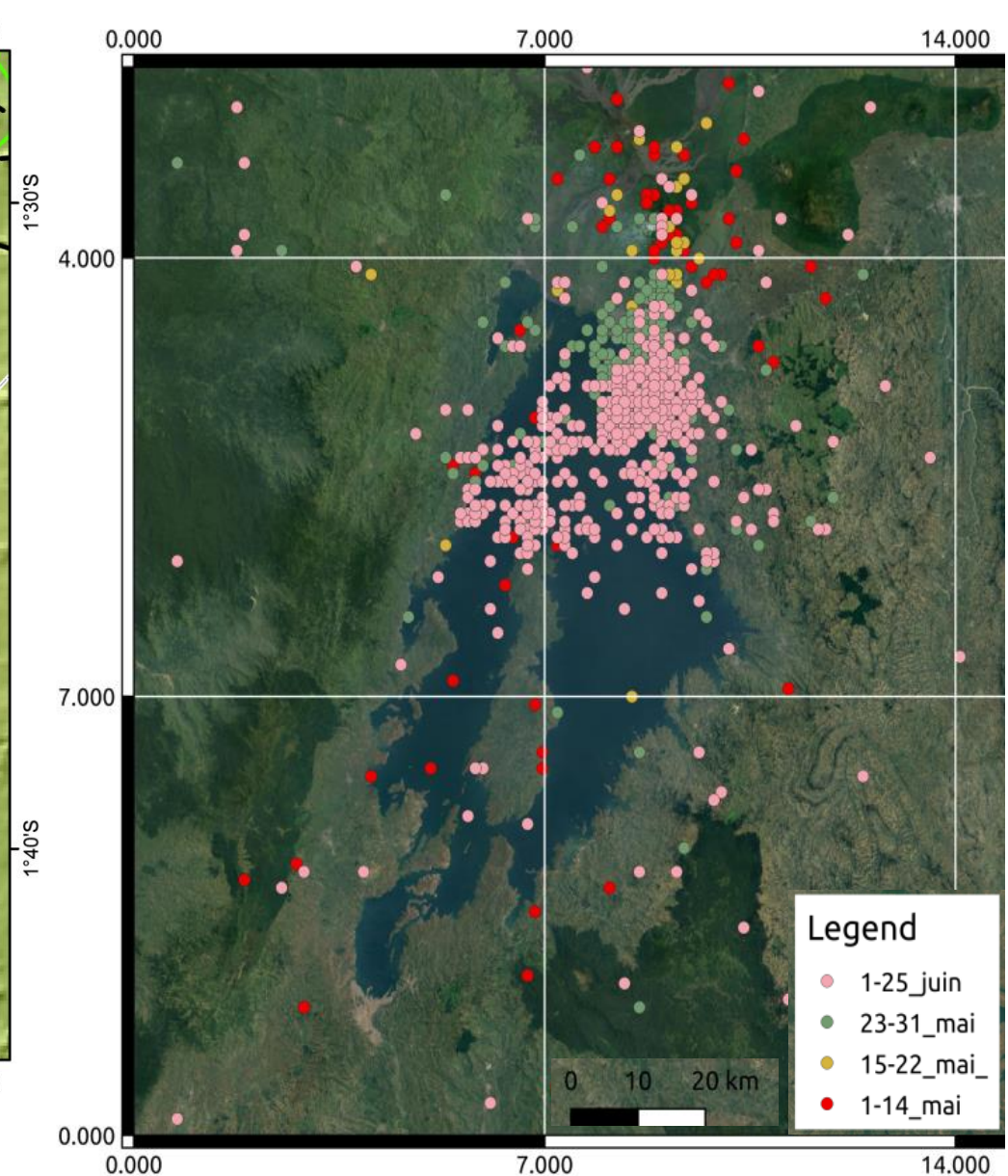
Local geologic and geodynamic setting increase the risk for limnic eruption: about 5 millions people at risk

January 2002, Lava flowing in lake Kivu



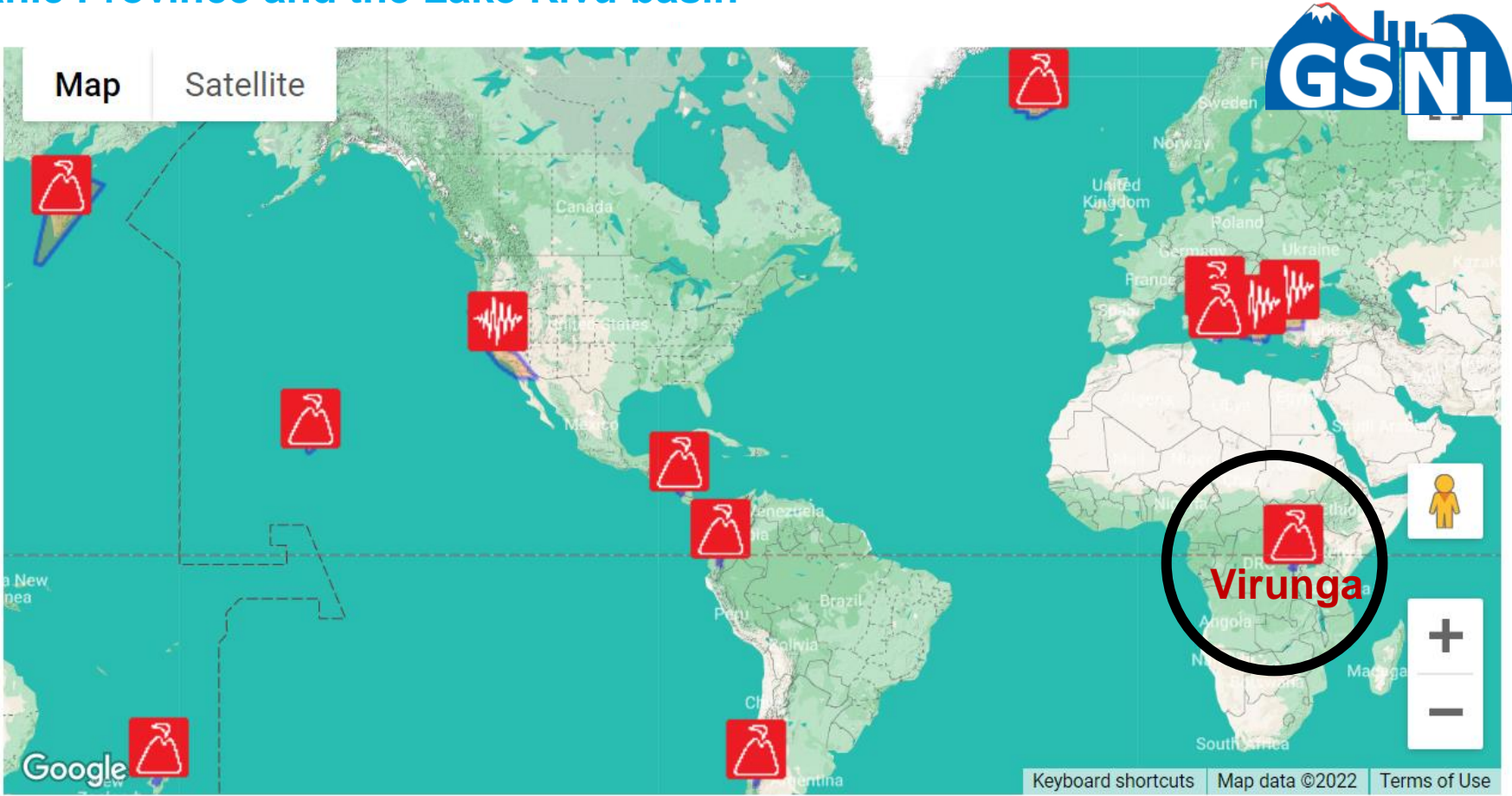


Eruptions have already occurred in the lake and along the Shoreline; which show that new eruptions with vents in the lake or closer are still possible



Strong seismicity during the 2021 eruption, and that gave fear for eruptive vents to open inside the lake

November 2017: establishment of a permanent Supersite in the Virunga with the aim of improving the geophysical scientific research and Geohazards assessment in support of Disaster Risk Reduction in the Virunga Volcanic Province and the Lake Kivu basin



Virunga Supersite specific objectives are :

- 1. capacity building of local scientists, which will help to improve the data collection methods, processing capacity and proper interpretation**
- 2 increase, on a fair basis, regional and international collaboration for the monitoring of the Virunga active volcanoes and the stability of Lake Kivu with the aim of preventing the related risks,**
- 3. access Earth Observation satellite data, for the monitoring and understanding of the volcano processes,**
- 4. identify possible funding sources and obtain resources to develop GVO monitoring and scientific capacities.**

2. Key Roles the Virunga Supersite has played to improve volcano research, volcano monitoring and Geohazards assessment in support of DRR

2.1. Training of local scientists

2.1.1. Training provided by the Volcano Disaster Assistance Program, at the CSAV in Hawaii and in Vancouver

Training, Hawaii at the CSAV

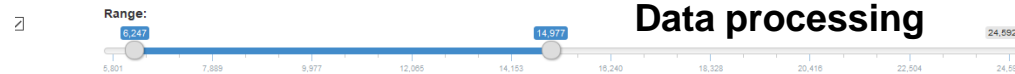
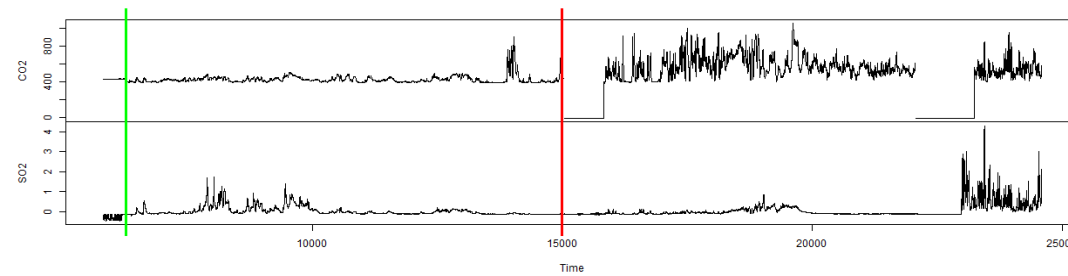
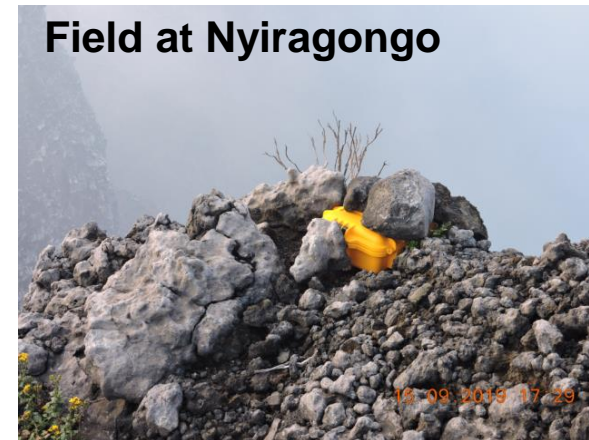


9/15/2019 14:18 - 9/15/2019 16:43

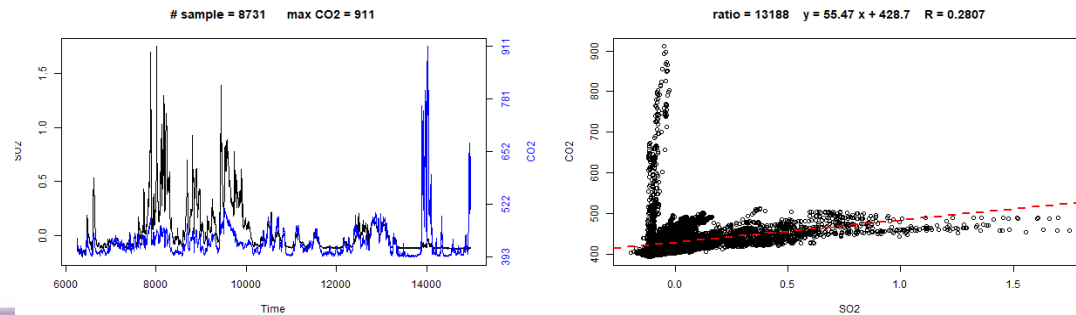
Training, Vancouver



Field at Nyiragongo



Data processing



This year, 2 of our scientists could not attend the CSAV courses, but will attend next year

A GVO Junior researcher is attending a two years masters in volcanology at the University at Buffalo, Department of Geology and is working on the reconstruction and modeling of lava rheology at Nyiragongo Volcano



A GVO Junior researcher is attending one year training in volcano seismology at the Istituto Nazionale di Geofisica e Vulcanologia (INGV), Osservatorio Etneo - Sezione di Catania; Italy



The Volcano Active Foundation has paid the fees of 1 researcher and 1 researcher to attend 2 years master program (locally)



The Virunga Supersite has participated and advised for the creation of Linda Project



- ☐ Linda Project is a community-based solution providing a sustainable safety net for the Goma Volcano Observatory to accomplish its core mission: monitoring the Nyiragongo, Nyamuragira, and Lake Kivu. The Linda Project is powered by the Congolese diaspora and the academic, scientific, tech, and business communities; GVO senior researchers included.
- ☐ The Linda Project is based on the idea that solutions rooted in the targeted community are the most resilient
- ☐ The Linda Project is also a strong advocate for OPEN DATA science in studying the Virunga volcanoes.
- ☐ Linda Project has financially supported 3 GVO junior researchers, and seismic + GNSS networks

2.2. Built a regional and international collaborating scientific team for the monitoring of the Virunga active volcanoes and the stability of Lake Kivu with the aim of preventing the related risks

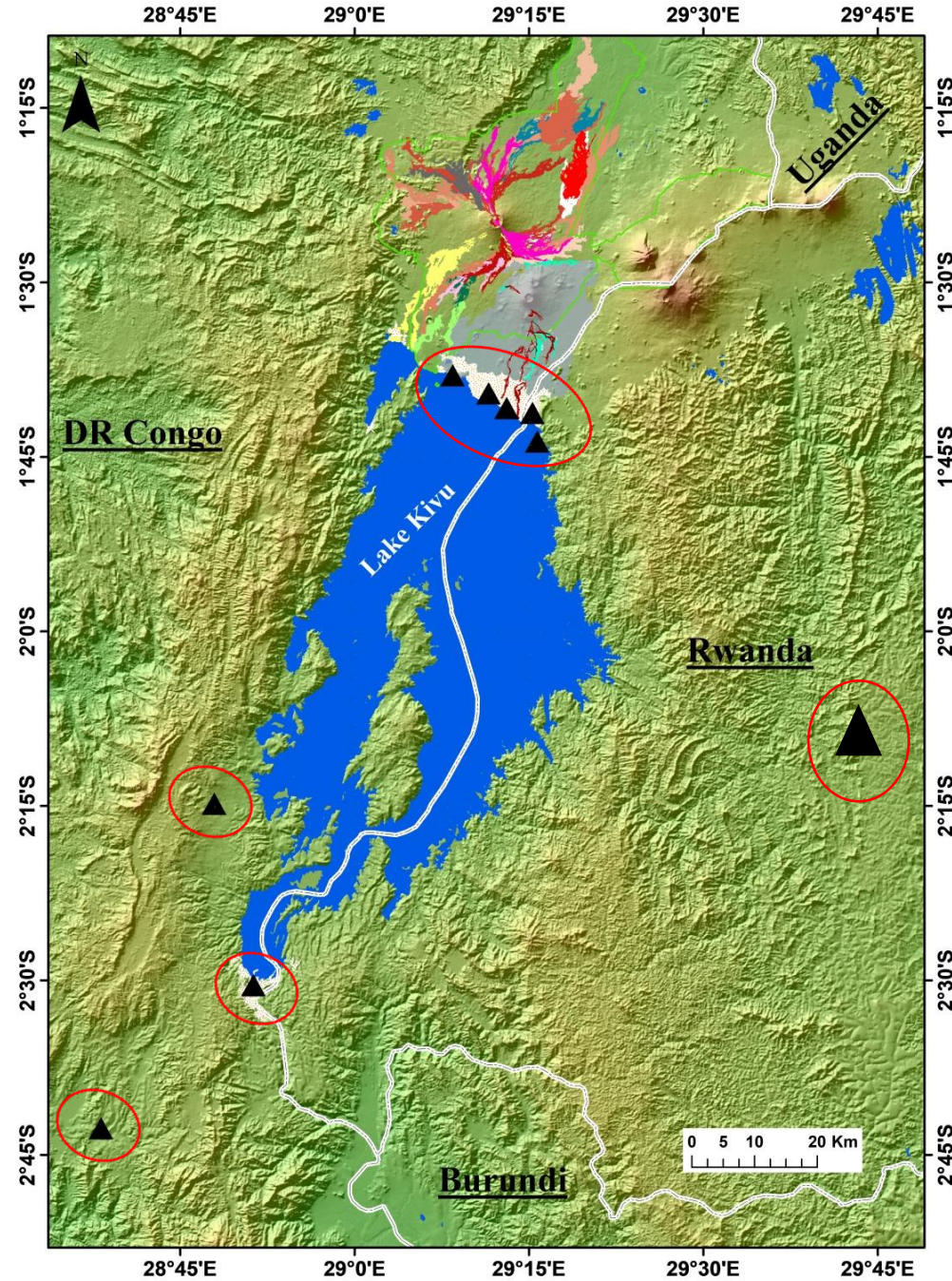


+ 5 international agencies

Local-Regional network

The Virunga supersite is now a network of local scientists from 3 institutions (Universities and Research Centers)

- 5 in DR Congo
- 3 in Rwanda



2.3. Supporting GVO for ground-based data collection and processing

1. **The Goma Volcano Observatory is presently building up its own seismic network, and in addition to the DRC government involvement, GVO received support from:**
 - ☐ VDAP that donated a server and computers to help in real time processing of seismic data, as well as technical support
 - ☐ Linda Project that donated a Machine to Machine Gateway for direct data telemetry from the field to GVO, modems for data transfer, technical support
 - ☐ At present, GVO seismic network is sending in real time, data from 7 stations and processed at GVO
2. **The VDAP has donated to GVO one Mobile MultiGAS and one MultiGAS station for real time CO₂, SO₂ and H₂S measurement**
3. **The GEO-GSNL has donated 5 GNSS stations to GVO, the LindaProject will provide the solar panels and batteries to deploy these stations in the field**
4. **Further is coming soon : seismic network improvement, GNSS network establishment from both the DRC government and partners**

2.3. Supporting GVO satellite data collection and processing

Open access to the Data from the ESA Geohazard Exploitation Platform

The screenshot displays the 'geohazards' platform interface. At the top left, the 'geohazards' logo is next to a search bar labeled 'Free Text Search'. To the right of the logo, a small icon and text state 'Access to Publicly available data, products and more'. On the top right, there are two tabs: 'EO Data' (selected) and 'EO-based products'. A red circle highlights a dropdown menu under 'EO Data', which lists the following satellite data sources: COSMO-SkyMed, ENVISAT ASAR Image Mode, ERS-1 SAR Image mode, ERS-2 SAR Image mode, Landsat 8, Pleiades, Sentinel-1, Sentinel-2, Sentinel-3, SRTM, and TerraSAR-X Haiti RO. The background of the interface is a world map showing major landmasses and oceans. At the bottom left, a date selector shows '2005-01-01'. At the bottom right, there is a small text line: 'PROGRAMME UNDER GRANT AGREEMENT N° 871121' and the European Union flag.

geohazards tep

Access to Publicly available data, products and more

EO Data EO-based products

Free Text Search

2005-01-01

PROGRAMME UNDER GRANT AGREEMENT N° 871121

The CEOS supports the Virunga Supersite with COSMO-Skymed and Pleiades

2019-2020

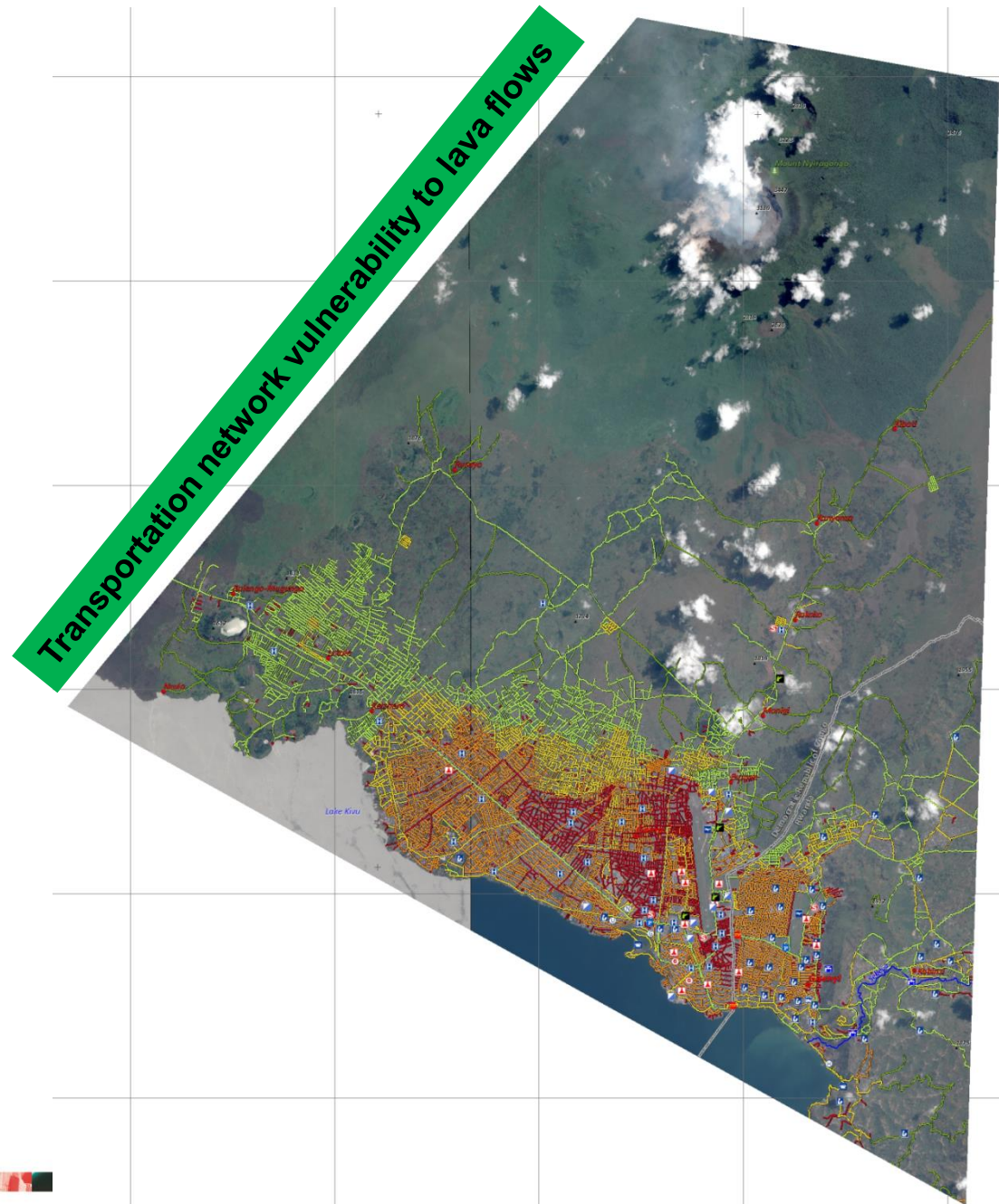
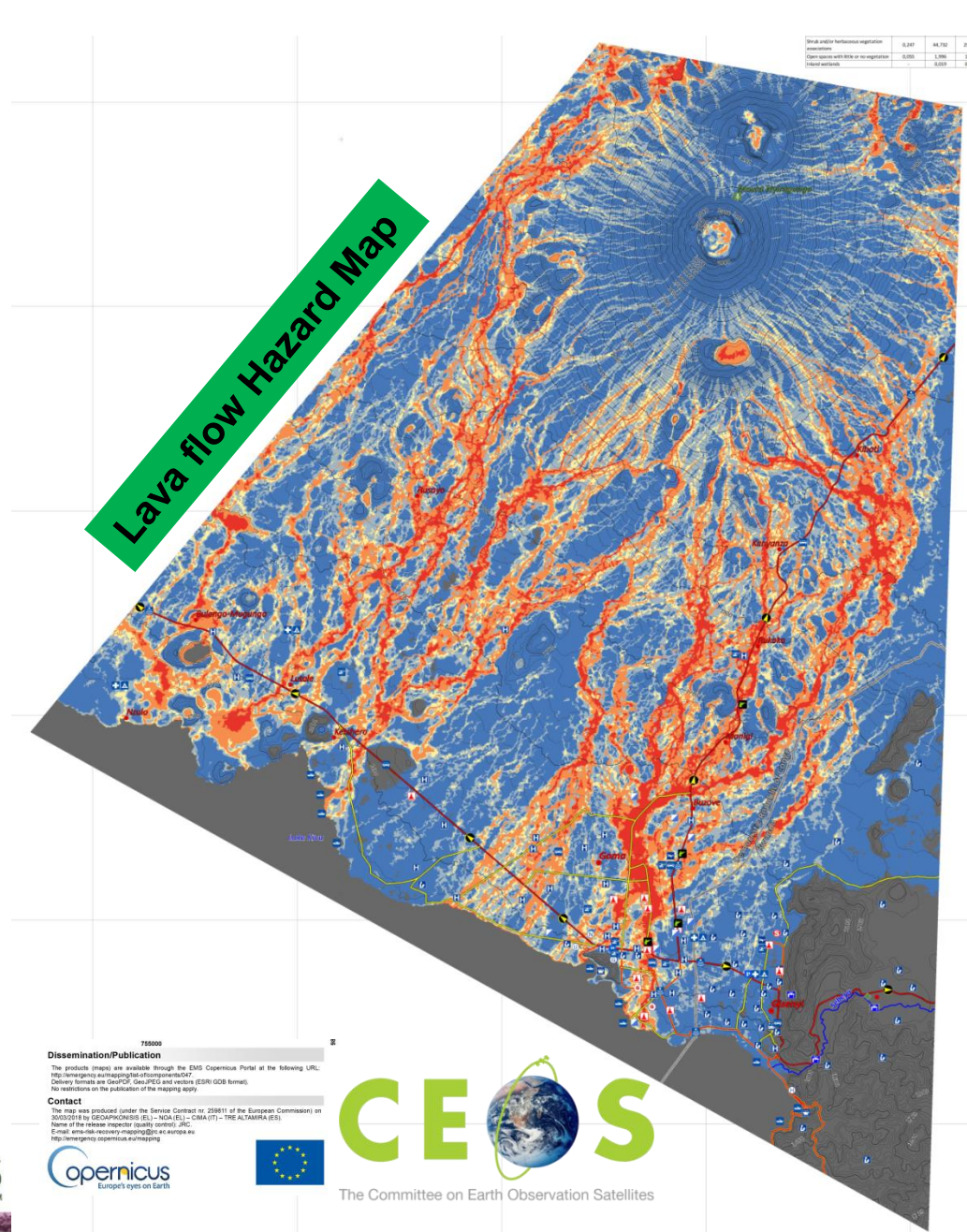
Agenzia Spaziale Italiana (ASI)	COSMO-Skymed: entire archived imagery over the AOI + 100 new products/year for a period of 2 years
Centre National d'Etudes Spatiales (CNES)	Pleiades: quota of 9 images tristereo (on the basis of one Pléiades monoscopic scene 400km ²) / year which is roughly equivalent to 3.600km ² of tristereo acquisitions / year, for a period of 2 years. Total ~22.000 km ² .

CEOS agencies intend to support Virunga Volcanoes Supersite with the following data resources (over a period of 2 years):

2021-2023

Agenzia Spaziale Italiana (ASI)	COSMO-Skymed: 200 products per year
Centre National d'Etudes Spatiales (CNES)	Pleiades: 11000 km ² (to be divided by 2 for stereo or 3 for tri-stereo)
Comisión Nacional de Actividades Espaciales (CONAE)	SAOCOM 1: 200 scenes per year

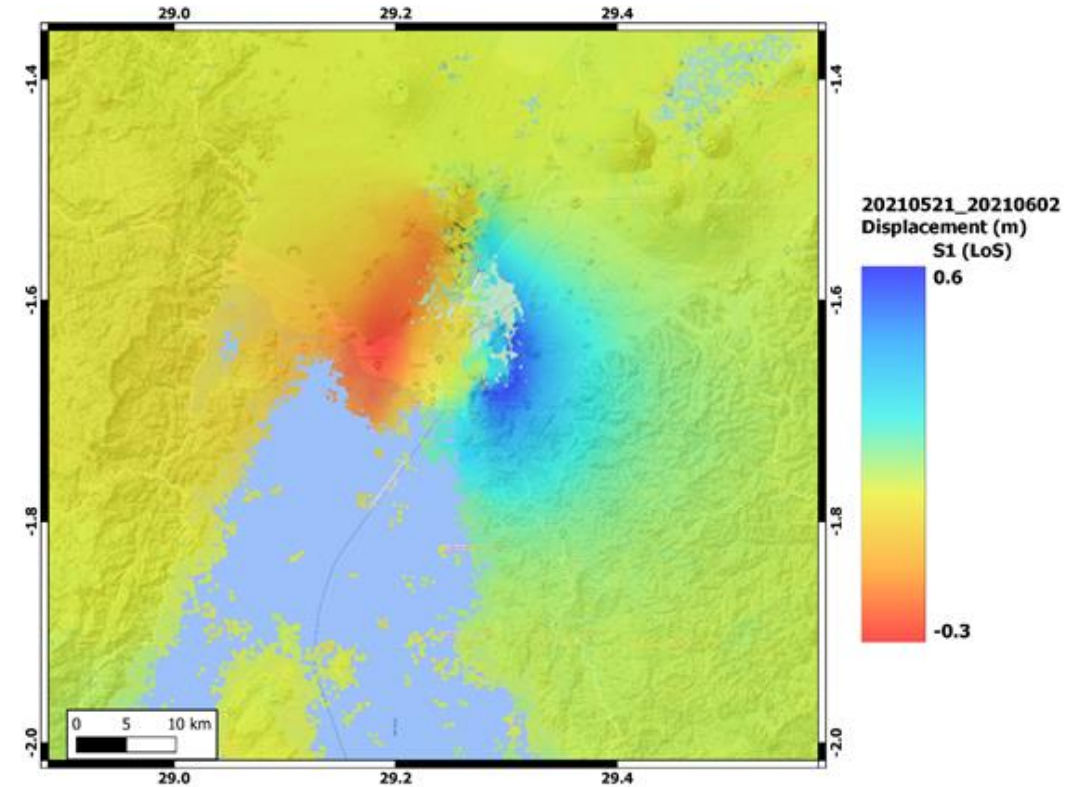
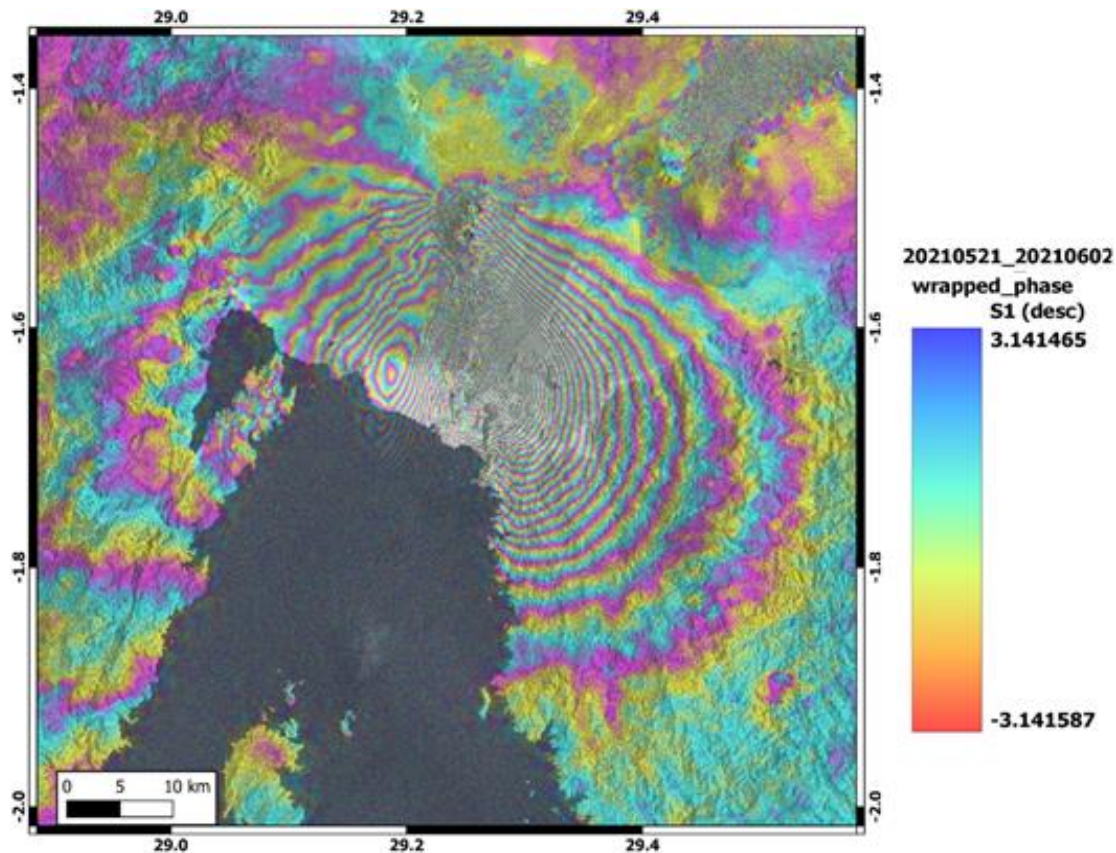
The data has allowed the production of Emergency and Management Service Risk & Recovery Mapping



The data has supported the response to the 2021 Nyiragongo eruptive crisis

- ❑ **Pre-eruptive 2020-2021 InSAR: CSK data analysis from Sentinel-1 show a deflation of the summit area of Nyiragongo and Nyamuragira volcanoes amounting to few cm/yr Line of Sight (LOS).**

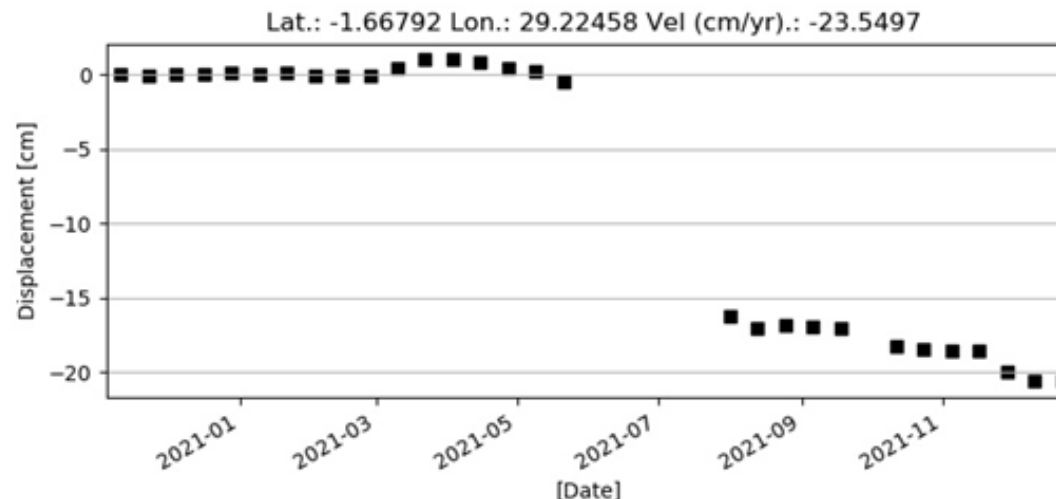
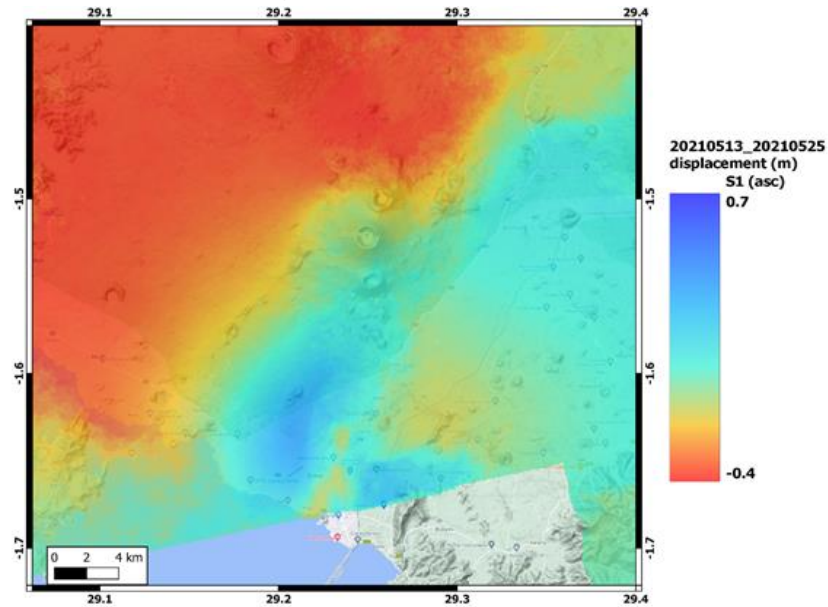
Descending S1 syn-eruptive wrapped phase, covering 21 May 2021 - 2 June 2021.



Descending S1 syn-eruptive cumulative displacement (21-05-2021/02-06-2021). Blue color means movement towards the satellite, red away from the satellite, along the LOS direction

The 2021 Nyiragongo eruptive crisis monitored by multi-sensor satellite remote sensing data

S1 ascending syn-eruptive cumulative displacement map (13-05-2021/25-05-2021). Blue color means movement towards the satellite, red away from the satellite, along the LOS direction.



Descending S1 pre- syn- and post- eruptive mean ground velocity map (10-11-2020/23-12-2021). Blue color means movement towards the satellite, red away from the satellite, along the LOS direction.

Descending S1 pre- syn- and post- eruptive displacement time series example in Goma city. The syn-eruptive jump in May is evident.

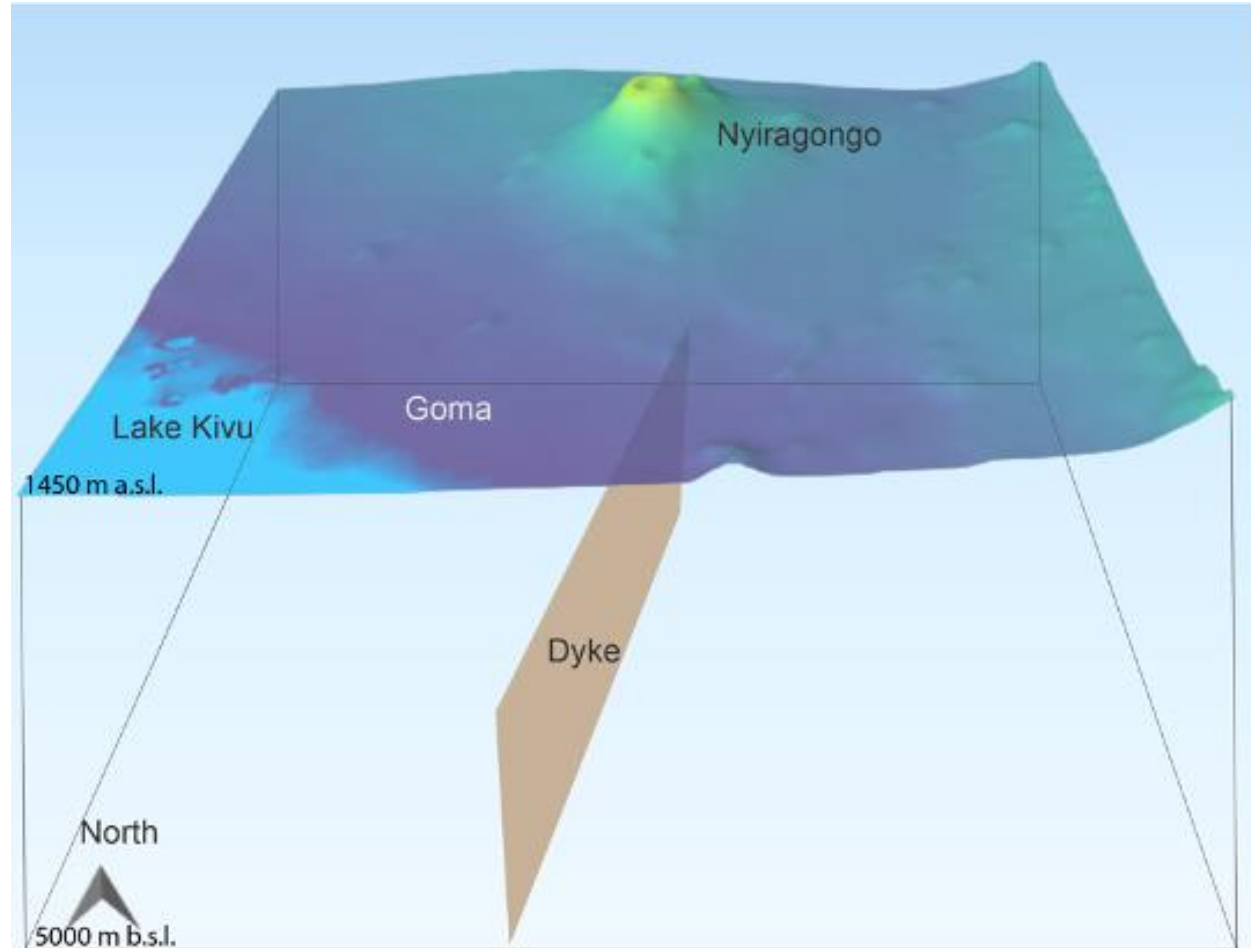
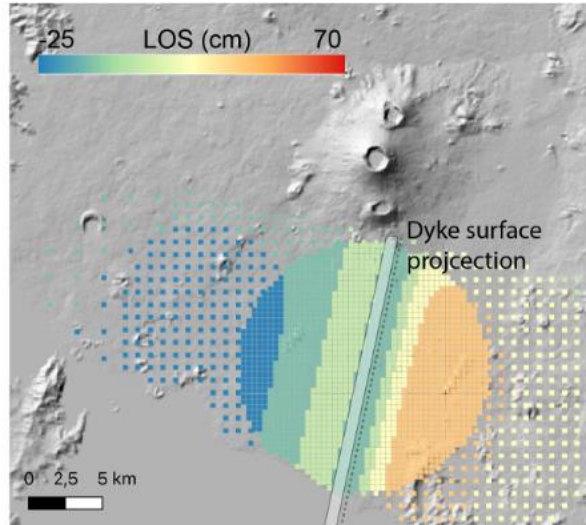
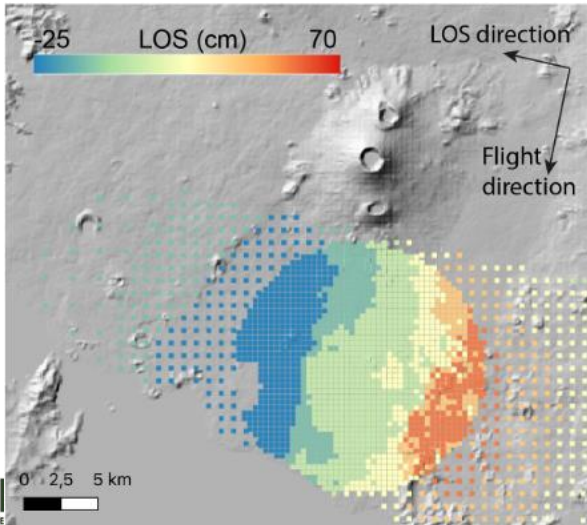
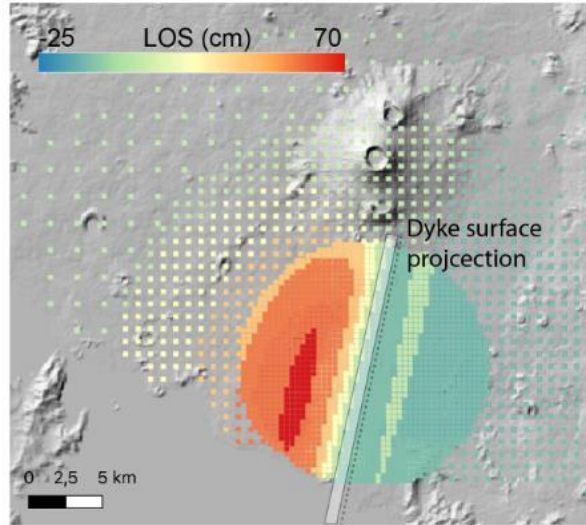
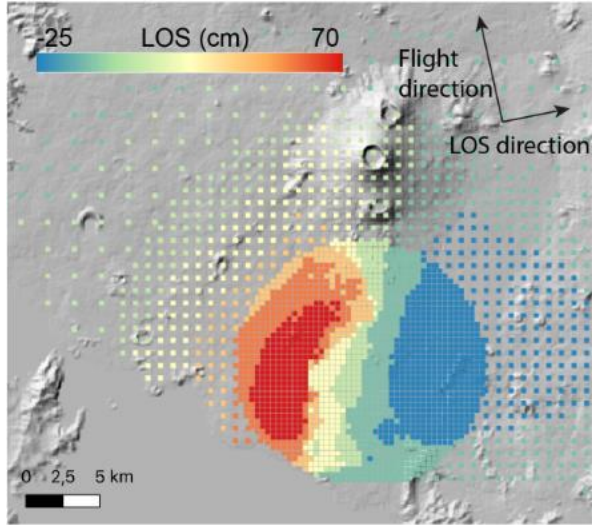
Modelling of the Nyiragongo 2021 eruption from InSAR data

TLC East (m)	TLC North (m)	TLC depth (m)	Length (m)	Width (m)	Strike (°)	Dip (°)	Opening (m)
751400	9826800	1400	18000	5000	192	82	2.0

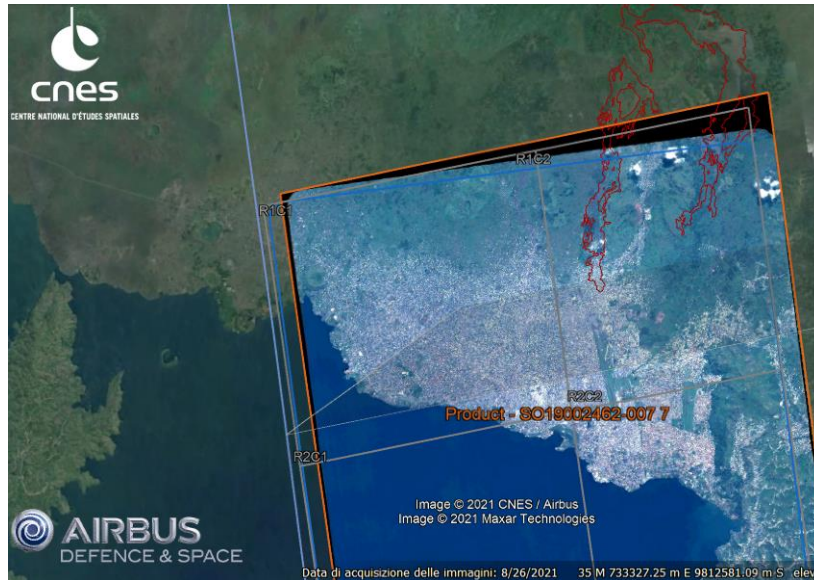
Results of the dyke modelling.

Subsampled S1 InSAR data in descending orbit.

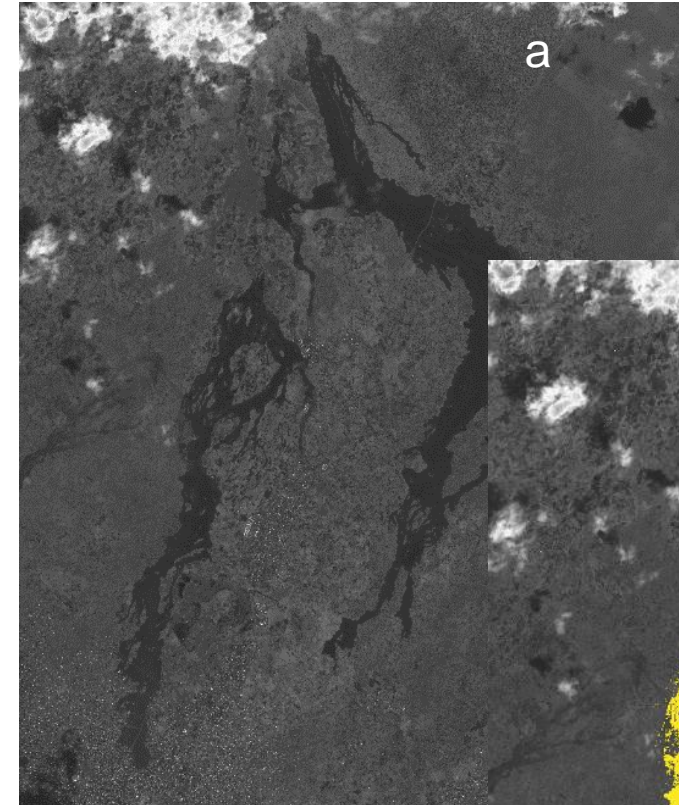
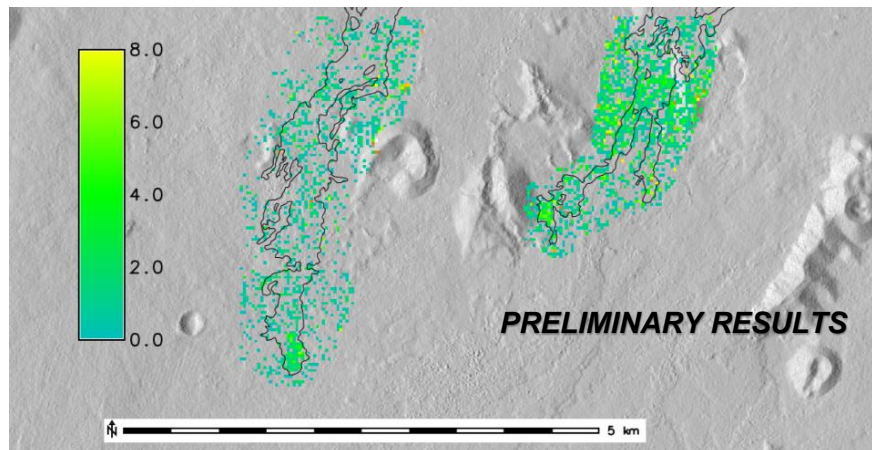
The surface projection of the dyke constrained by the inversion is reported on the right panel.



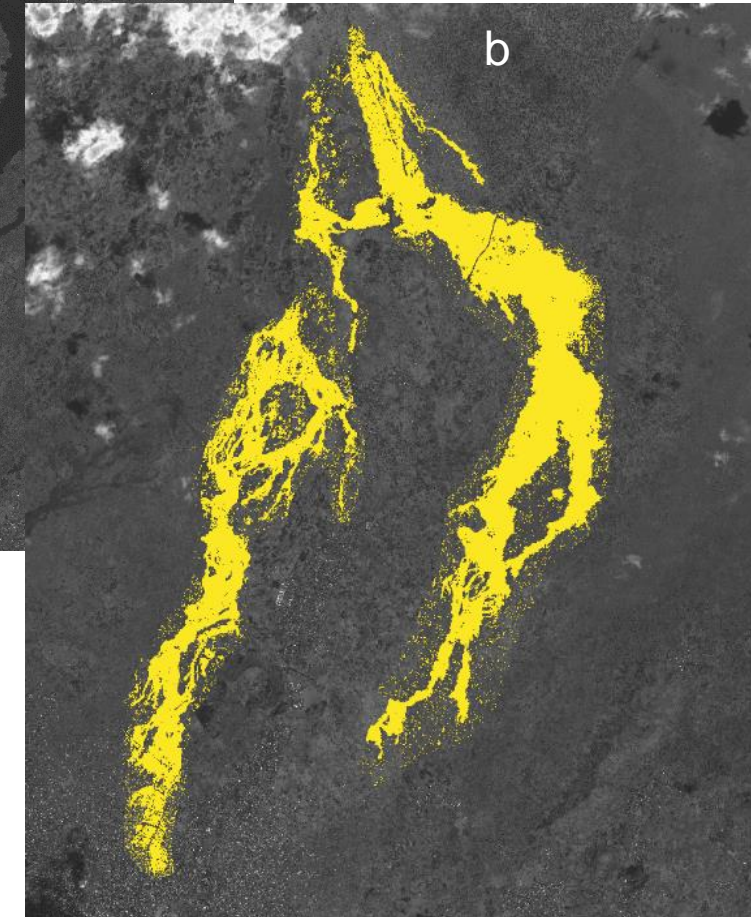
Thanks to Pleiades imagery we could retrieve the lava flow area



Two 1-meters DSMs were produced by using the MicMac (Multi-images Correspondances, Méthodes Automatiques de Corrélation) photogrammetric library developed by the French IGN (Institut Géographique National).



a) Pléiades image acquired on 12 November 2021; b) Lava flow field emplaced in May 2021 (yellow area).



2.4. Data Policy : Need for data sharing

=> Science for end users

The scientific community has to provide the local authorities with accurate information about the volcanic activity, the hazards in the Virunga region and Lake Kivu basin, risk prevention and management planning,...

We need to OPEN/SHARE the data for :

- **efficiency and quality of research: better understanding of the volcanoes and lake Kivu systems, the hazards sources and their characteristics**
- **Innovative and inclusive research**
- **GVO for monitoring purposes, during eruption or unrest events: for support decision making processes for risk prevention and response**
- **Regional understating of the geophysical processes, hazards sources and their characteristics**
- **Regional planning of risk prevention and management**
- **Training of local and regional scientists**



Opening/sharing the data is not putting the data online just after you have collected it !

The Virunga Supersite Data Policy, which was accepted by the GVO authorities:

EO data access : Open

- EO data= satellite images provided by the CEOS agencies
- Each agency grants the right to use the data through a License which details the conditions of use.
- Access to the EO data is granted to researchers only for scientific purpose and only upon the acceptance of the present Data Policy.
- Scientists are expected to involve local researchers in the processing and interpretation of EO data, to contribute to the building of local capacities, which is an objective of the Supersite.

Ground-based data access

- Ground based data and results should be made open access after publication or in any case **within 2 years (“embargo period”)since their collection/generation.**
- During the embargo period the data/results will only be available to the owner and to his co-authors, while the relative metadata will be openly available, so that the community is aware of the data/result existence.
- Even during the embargo period, the data/result owner is required to share its data for monitoring purposes, during eruption or unrest events, or for specific capacity building/training activities.

Long term Cooperation

Contact GVO General Director for signing a
Memorandum of Understanding

3. Present and future challenges

Main challenges: Implementation of the network at local and regional level, capacity building, equipment for ground based data collection, and lack of funds are the

(1) Acceptance of the New Idea (“common issue with accepting novelty”)

- by international partners already working with local groups
- by locally established realities (e.g. organisation, inter-institutional relations, limited nation & regional cooperation)

(2) Establishing a local network

- **Institutional** : at some institutions lack of infrastructures (e.g. computers, internet connection, [good] salary, stable electricity ...)
- **Personnel (workers)** : lack of minimum level or qualification, issue with age, wrong background,...
- **Lack of motivation** : for some institutions/personal, the Supersite should provide founding (salary, per diem...), **direct** training (come with the scholarship and give to people)

(3) Lack of equipment for ground based data collection, storage, processing

(4) The Virunga Supersite has no funds to support the activities

4. Conclusions

The Virunga Supersite is improving the volcano research, volcano monitoring and Geohazards Assessment in the Virunga Volcanic Province, and Lake Kivu basin through:

(1) Capacity building of local scientists

(2) The establishment of a scientific team that include regional and international scientists, who work together with the aim of yielding capacity building of local scientists

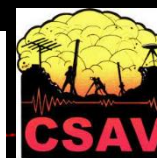
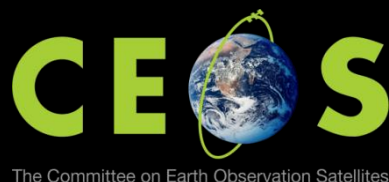
(3) Made open access a number of Earth Observation satellite data, for the monitoring and understanding of the volcano processes

(4) Supporting the building up of GVO ground-based data collection networks

(5) Etc.

Even though there is still much work and many challenges, the Virunga Supersite experience may serve as example for other low income countries with limited volcano research and monitoring resources, and we are ready to share our experience.

Thanks to our partners



...and many others

Thanks for your attention