Thesis subject

« Seismicity and the seismological model in the Virunga Volcanic Province (PPV) and the Kivu rift region»

Seismological model

Josué Subira

Advisors: **Julien Barrière, Corentin Caudron, Aurélia Hubert-Ferrari, François Kervyn**

My PhD thesis

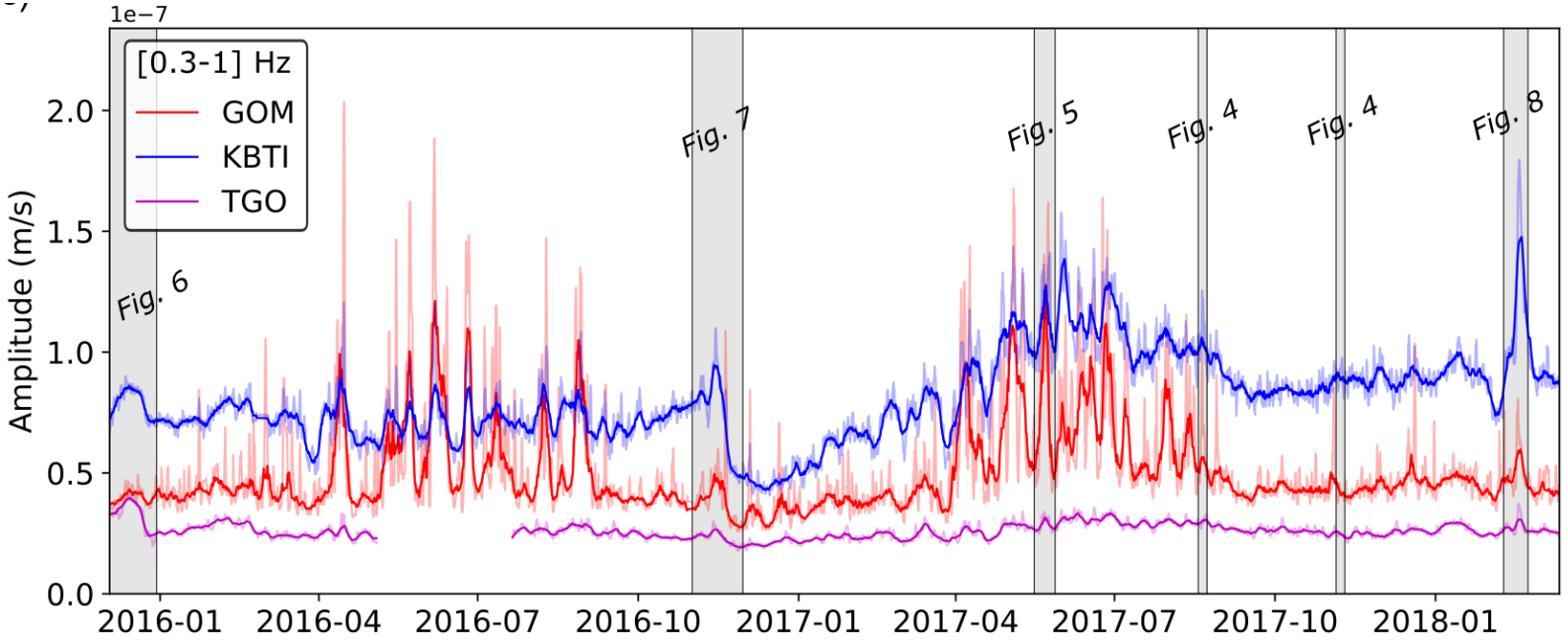
Goal of my PhD thesis in Seismology :
Developing and installing at GVO dedicated tools applied to seismic monitoring domain.

2 approaches chosen for better understanding magmatic processes behind the seismic signals

P1. Analyzing the volcanic seismic noise recorded at the stations

- **Detecting sources of shallow tremor at neighboring volcanoes in the Virunga Volcanic Province using seismic amplitude ratio analysis (SARA)**

- **Seismic amplitude measurements prior, during and after the May 2021 Nyiragongo flank eruption**



(Subira et al., 2023)

My PhD thesis

P2. Sismo-volcanic events classification

- **Earth velocity structure of the Kivu Rift**
- **Volcanic and tectonic seismicity patterns**

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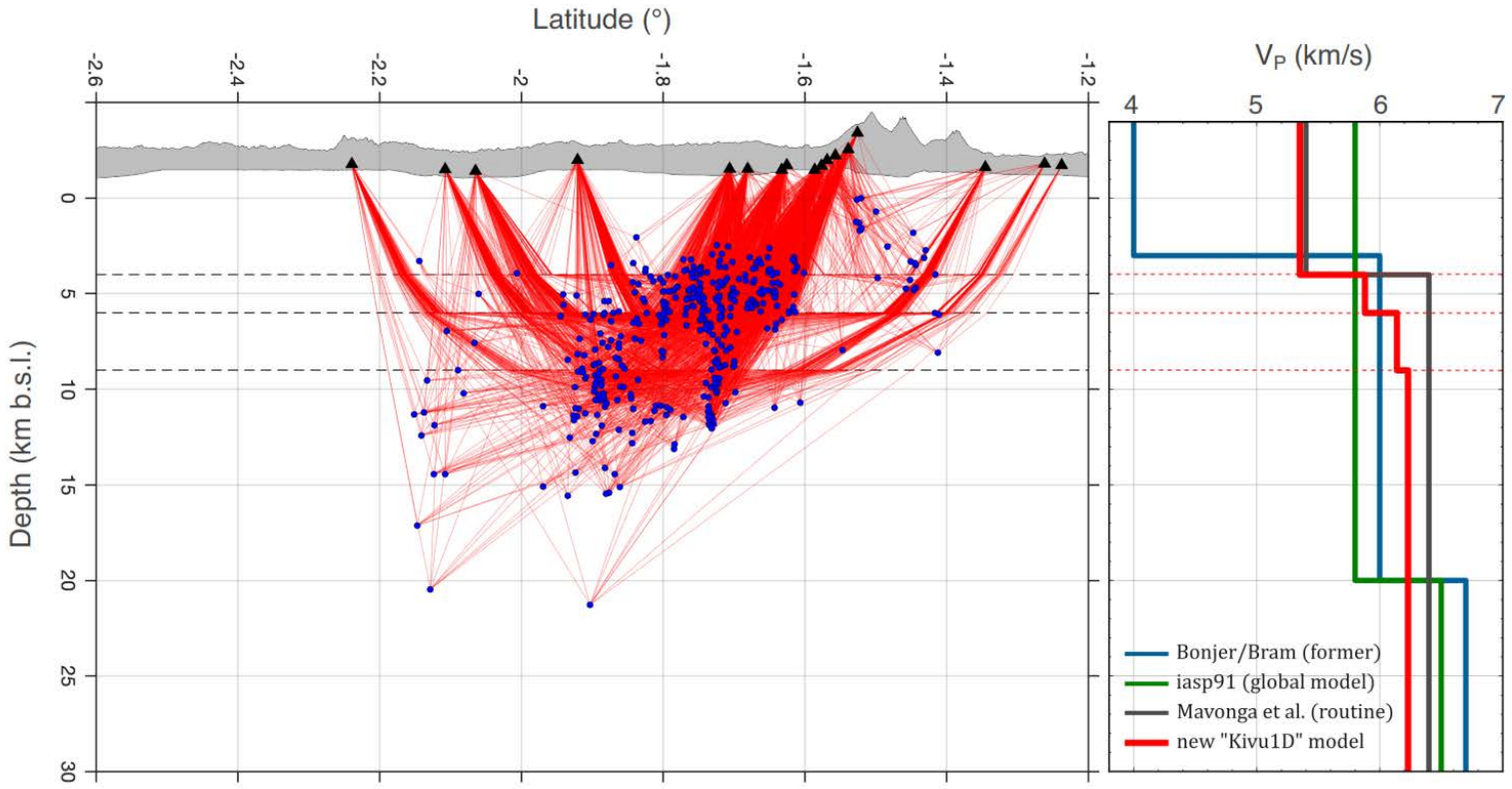

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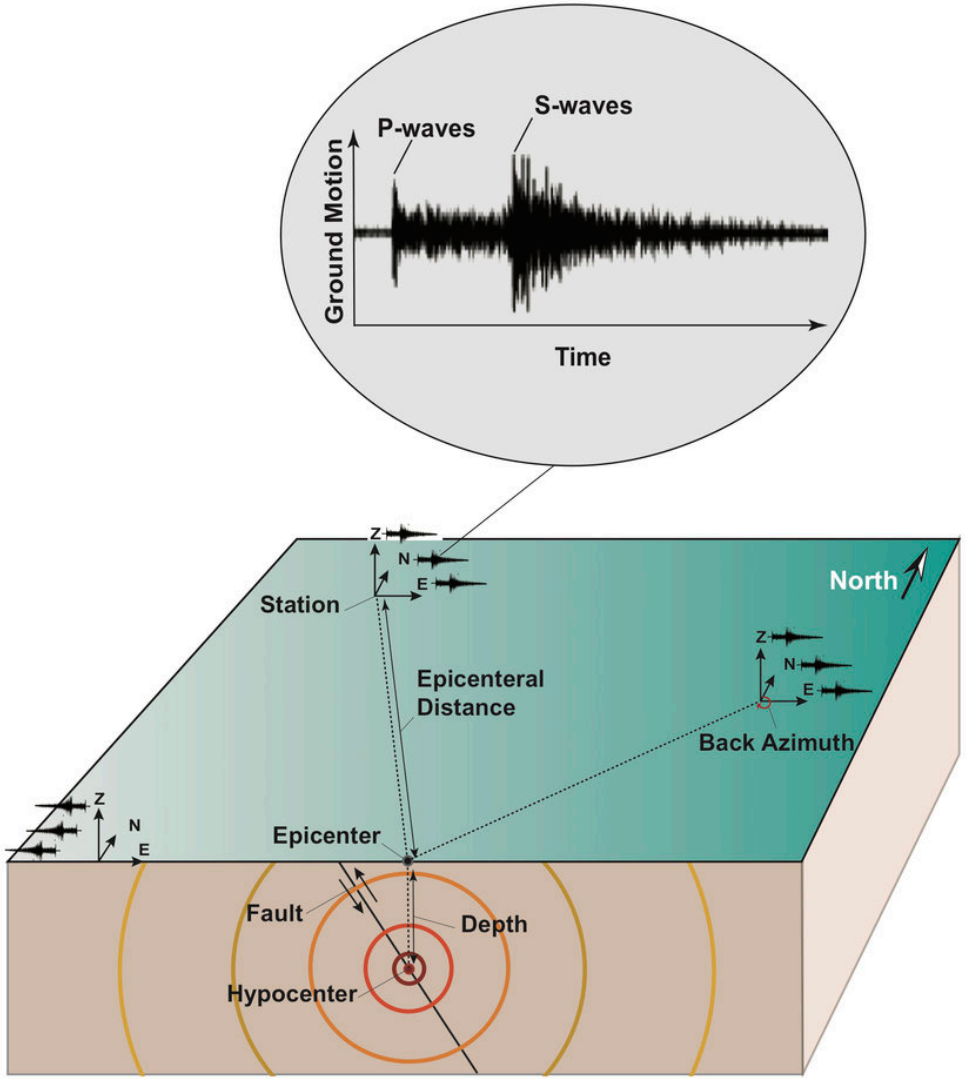
P2. Seismological model and seismicity patterns
1D Velocity model

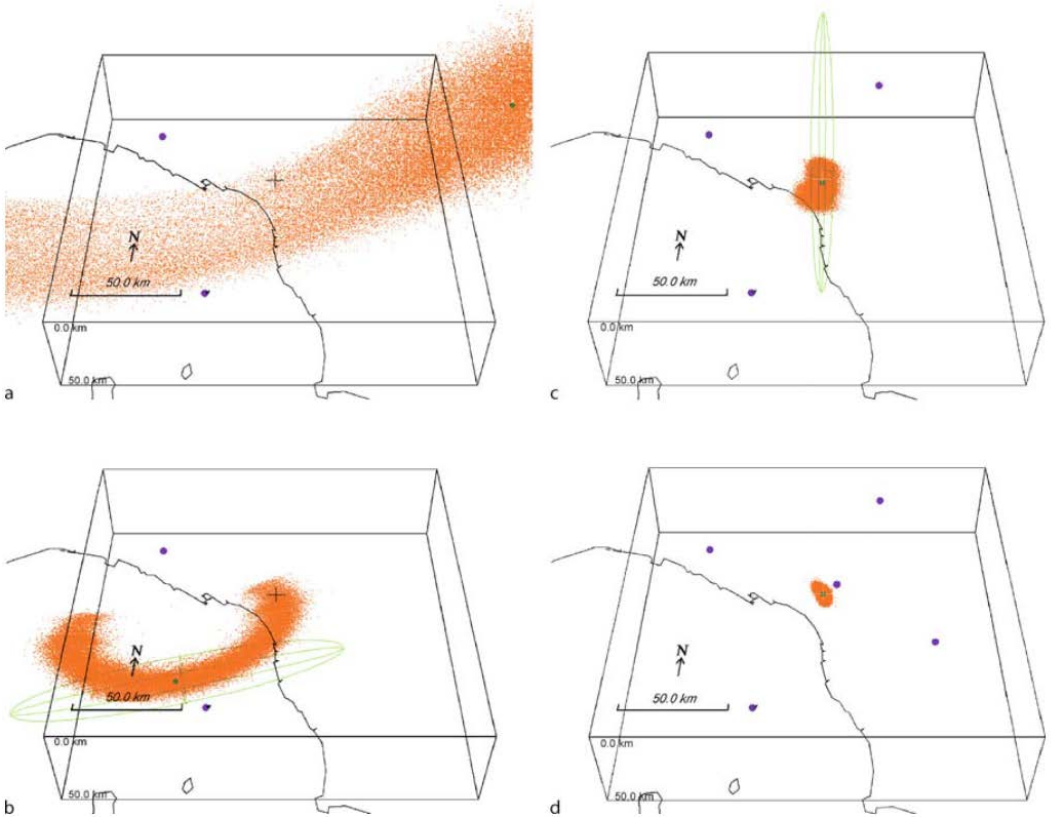
Introduction



- Earthquakes happen when there is a sudden movement of the rocks along a fault inside the Earth.
- Seismometers allow to detect and measure earthquakes by converting vibrations due to seismic waves into electrical signals, which we can then display as seismograms,
- Seismologists study earthquakes and can use this data to determine where and how big a particular earthquake is,
- The seismograms from different recording stations (network), can help to find out the epicenter of the earthquake. The time difference between the P- and S-waves tells us the distance the earthquake is from the seismometer.

P2. Seismological model and seismicity patterns
1D Velocity model

Introduction



(Lomax et al., 2009)

What parameters influence the earthquake location

- Network geometry and station coverage
- Picking quality (Incorrect Picks and Phase Identification)
- The Velocity or Slowness Model
- Location methods (linearized or direct-search methods)

Why the precise location ?

- Coordinate rescue operations
- To better understand the seismic hazard in a given region,
- Precise localization of earthquakes in a volcanic monitoring context is a key parameter for monitoring magmatic migration.

P2. Seismological model and seismicity patterns
1D Velocity model

Context and motivation

Volcanic eruptions

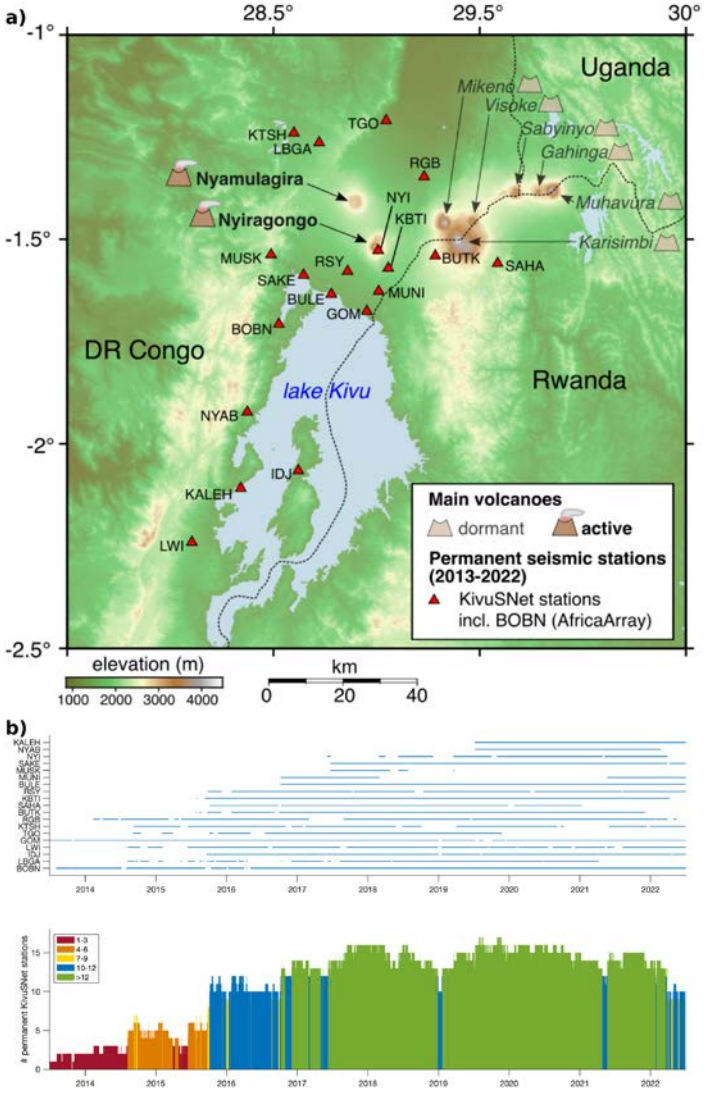
Earthquakes

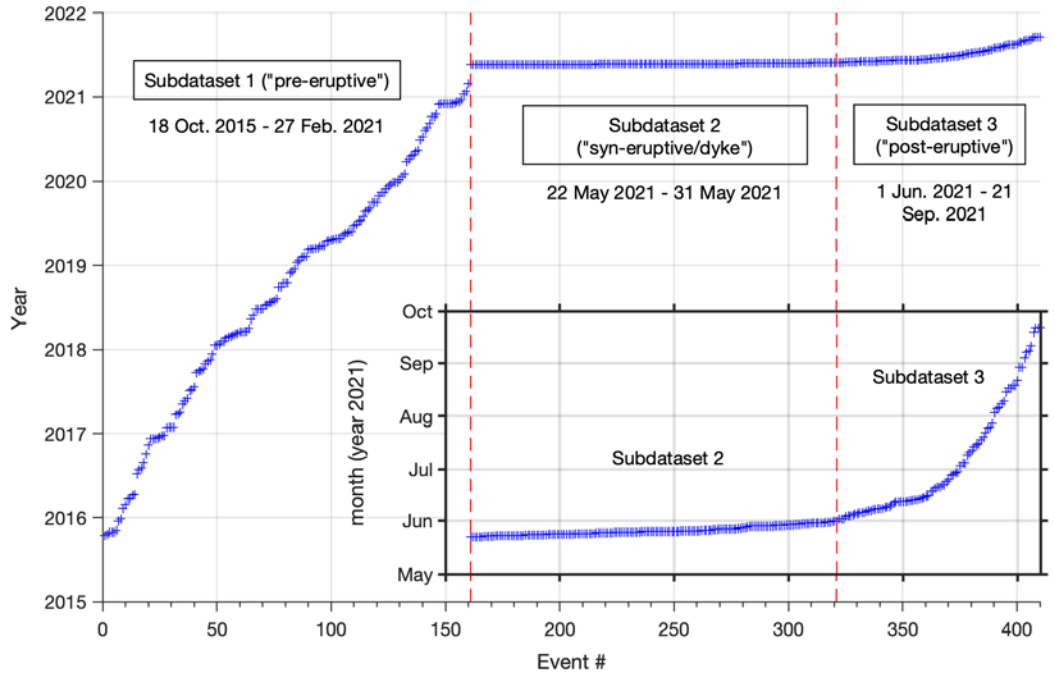
- In regions like the Kivu Rift and Virunga Volcanic Province (VVP), the ground velocity structure is poorly known,
- For moderate to large earthquakes, global solutions provided by international agencies (e.g, USGS, GEOFON) using the iasp91. Ex. USGS supplied earthquake locations for major events during the 2002 Nyiragongo eruption crisis
- Mavonga et al. (2010) provide a simplified model for the Virunga area using 2 seismic stations
- Opportunity to investigate a regional velocity model using KivuSnet (2013-2022), the new dense seismic network operated in the region

P2. Seismological model and seismicity patterns

1D Velocity model

Dataset selection and characteristics



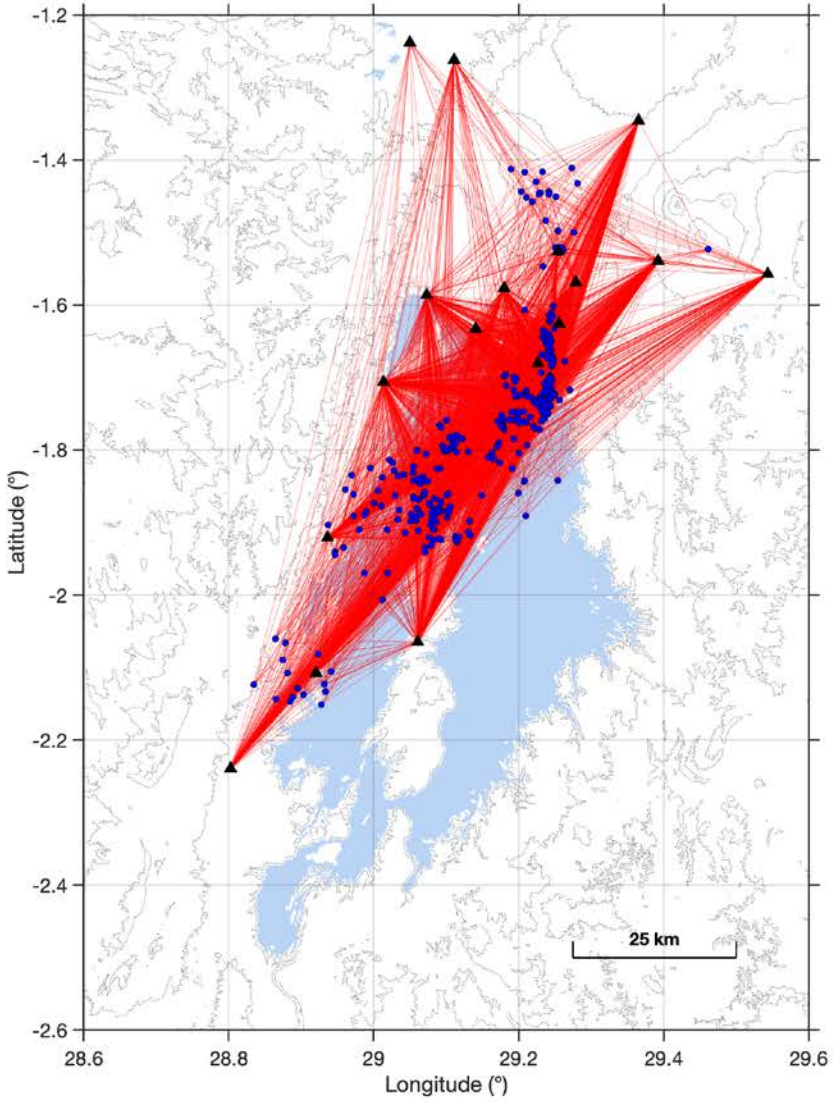


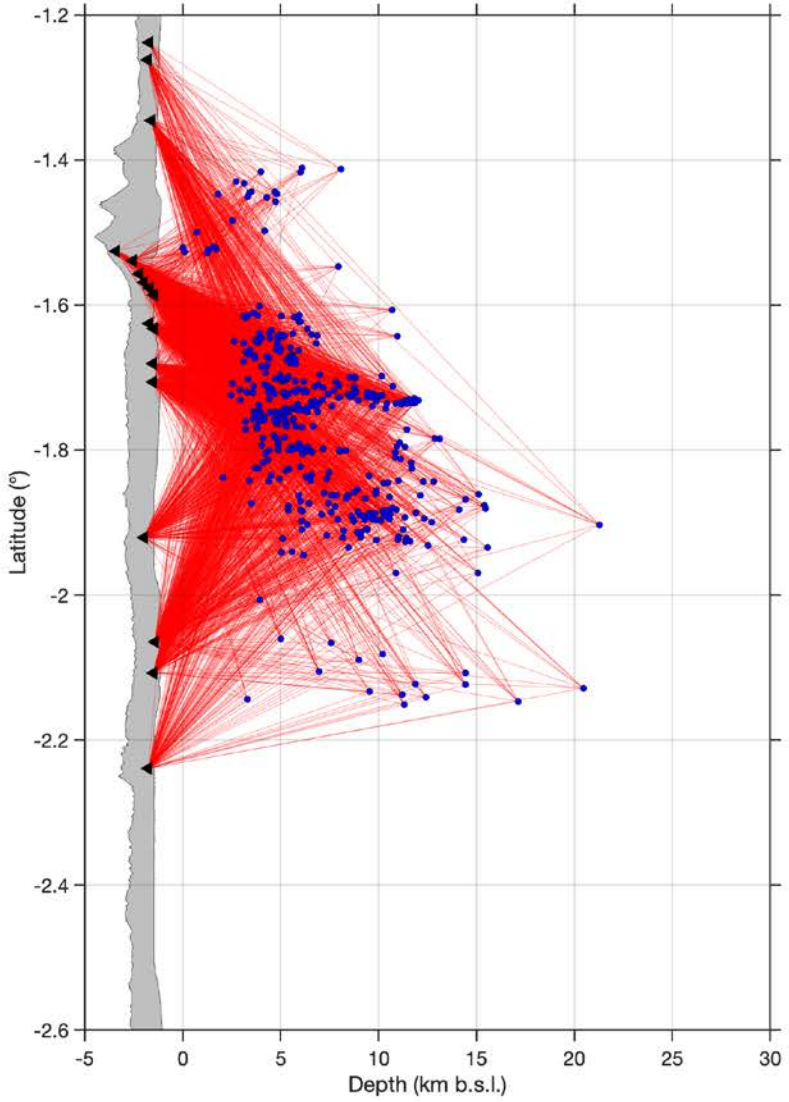
- Seismic event detection was performed using the traditional short-term average/long-term average (STA/LTA) detection algorithm implemented in the program CONDET.
- Manual picking of seismic phases followed the principles outlined by Bormann (2002) and Havskov and Ottemöller (1999) for local seismic events. Preliminary locations were obtained with the HYPOCENTER routine using the Mavonga et al. (2010) mode

P2. Seismological model and seismicity patterns

1D Velocity model

Dataset selection and characteristics





- We can visualize the region covered by the data and anticipate an average 1D minimum model encompassing the northern and western parts of Lake Kivu and the VVP around Nyiragongo and Nyamulagira volcanoes.
- The depths investigated range mostly from 0 to 15 km below sea level

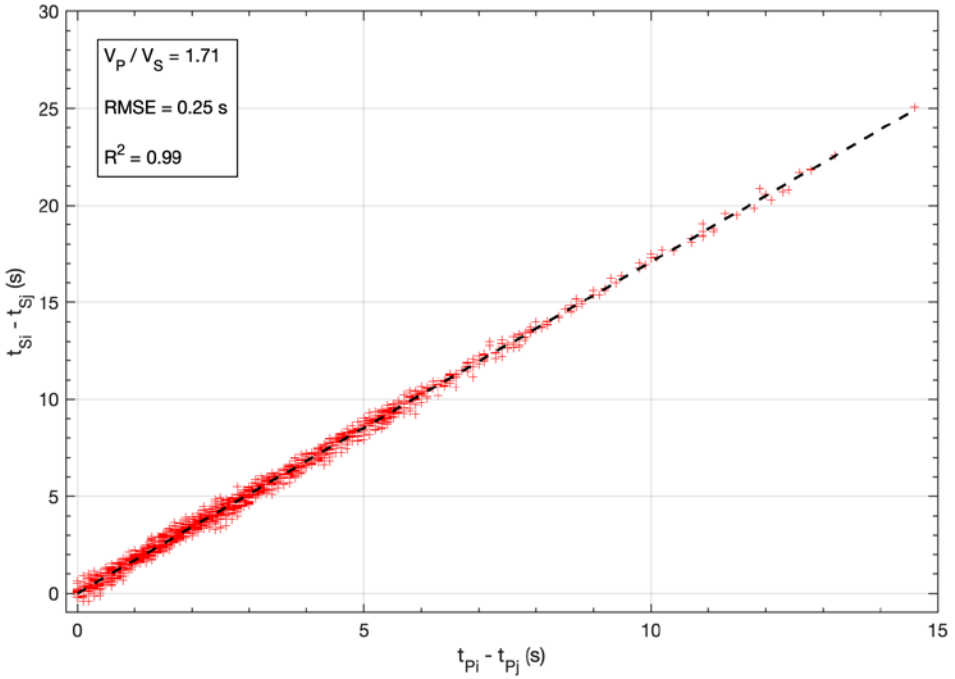
P2. Seismological model and seismicity patterns

1D Velocity model

Events selection and picking quality

- Manual pick (IP,EP,IS,ES)
- RMS < 1
- Minimum of 7 stations
- Gap < 180°
- >= 7IP, 8 Observations

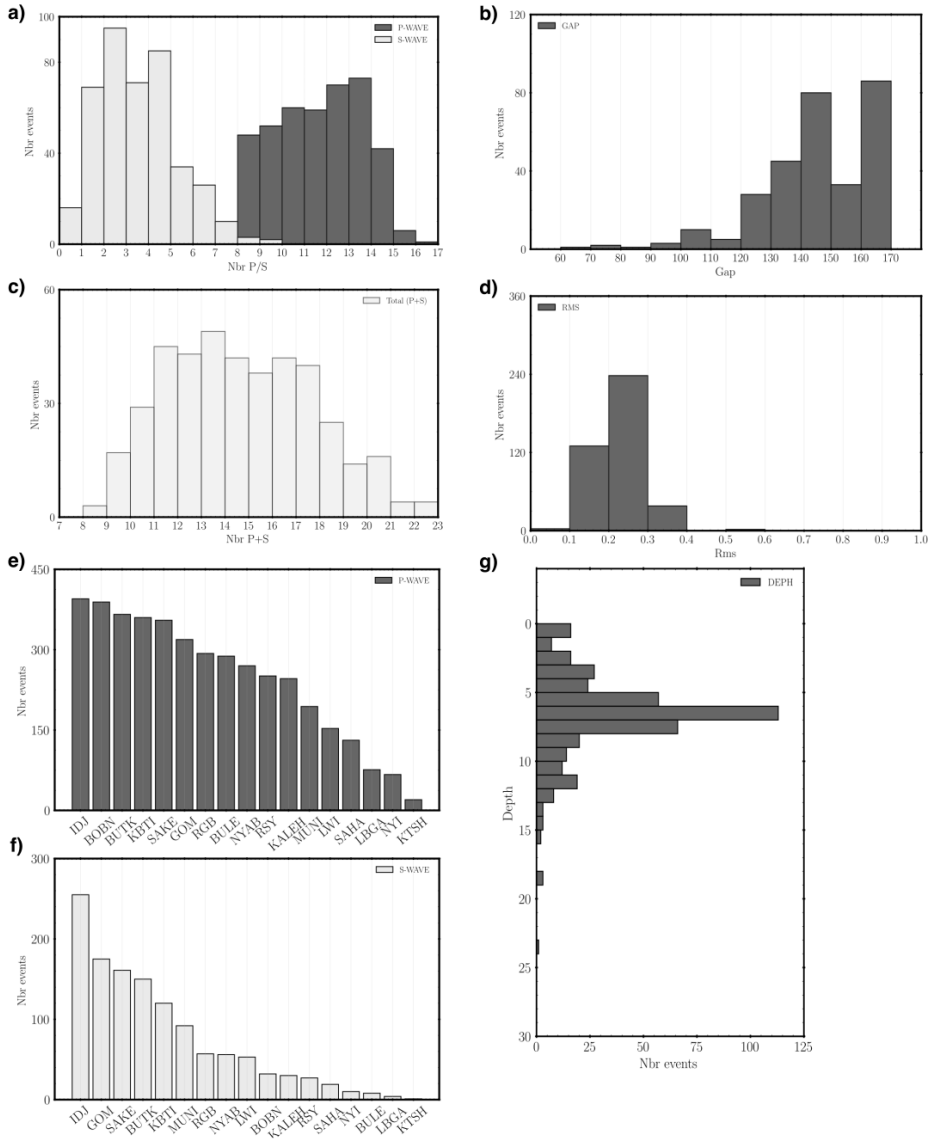
460 Events



- Wadati : no outliers
- Vp/Vs = 1,71 (RMS = 0,25s)
- Velest : only Ip observation are candidate for inversion.

410 Events, 4156 P-wave picks

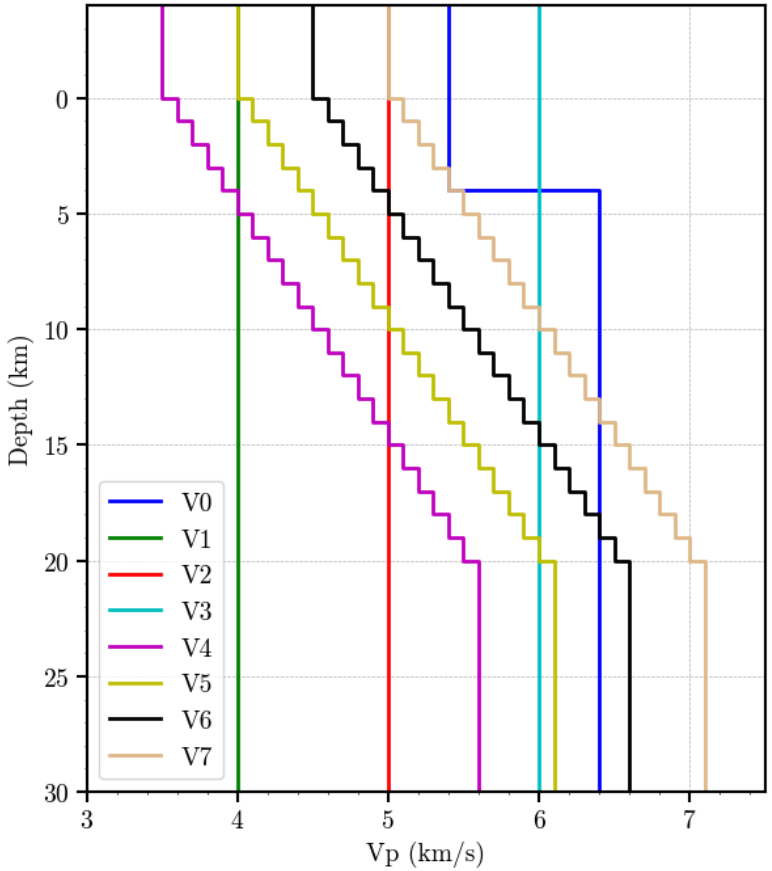
DB statistics

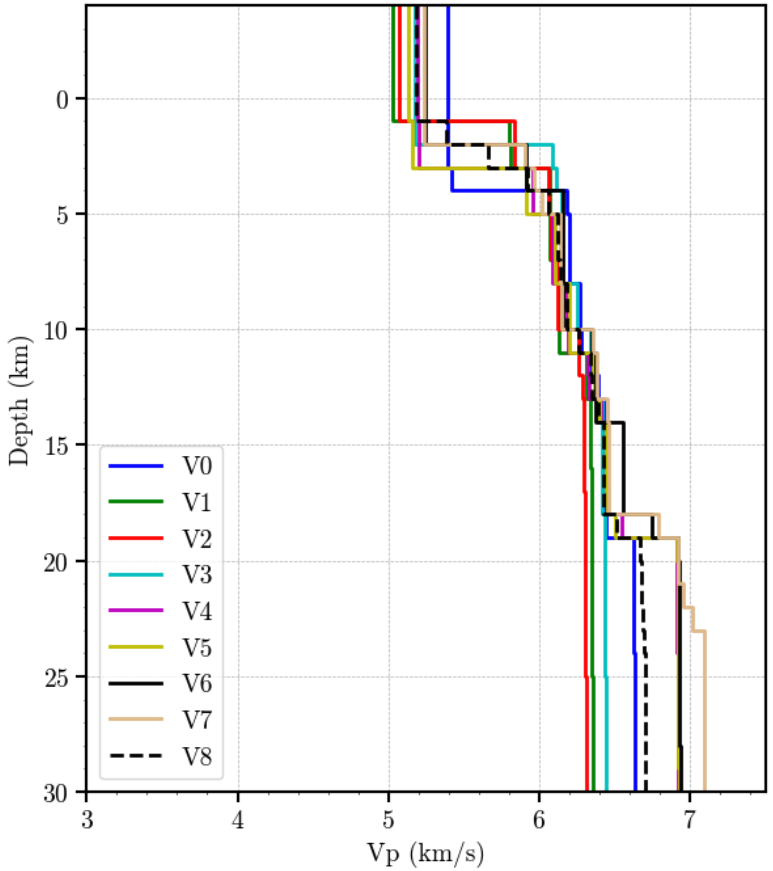


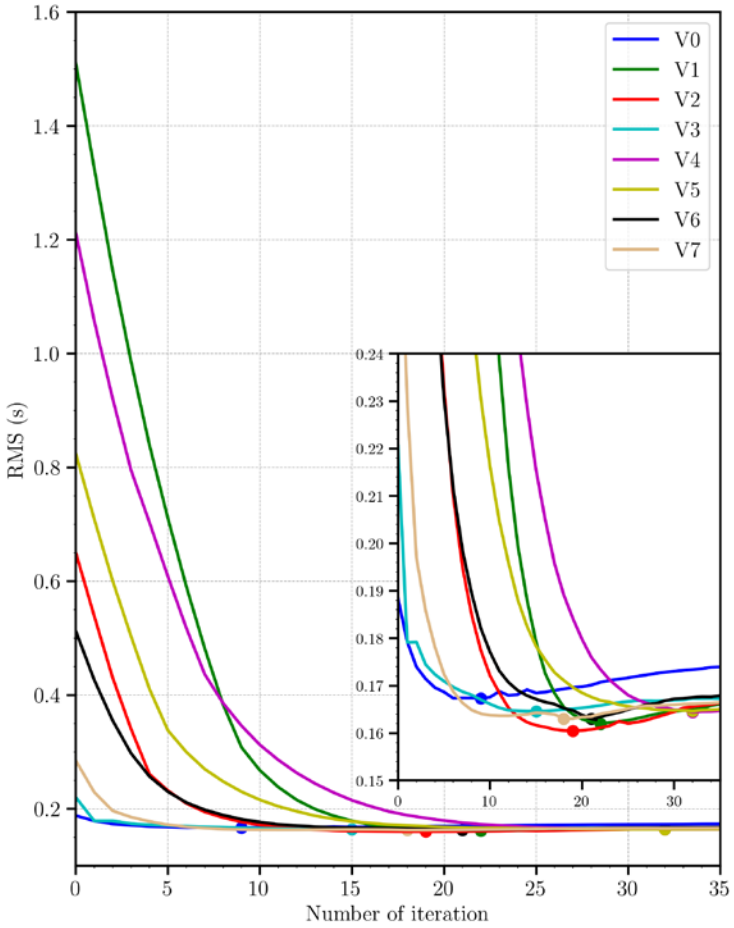
P2. Seismological model and seismicity patterns

1D Velocity model

Data processing: Initial models



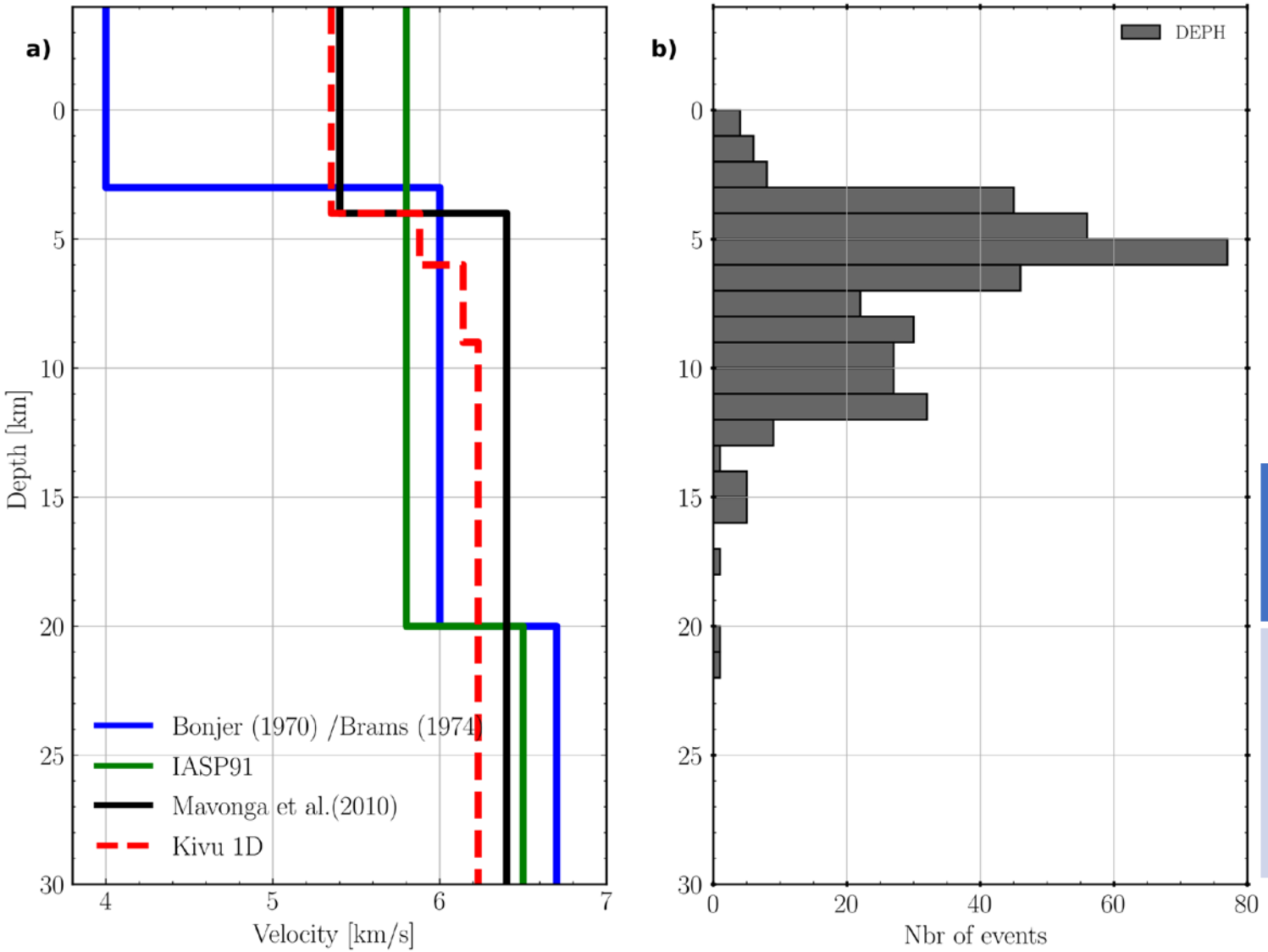




P2. Seismological model and seismicity patterns

1D Velocity model

Kivu 1D: A new local minimum model



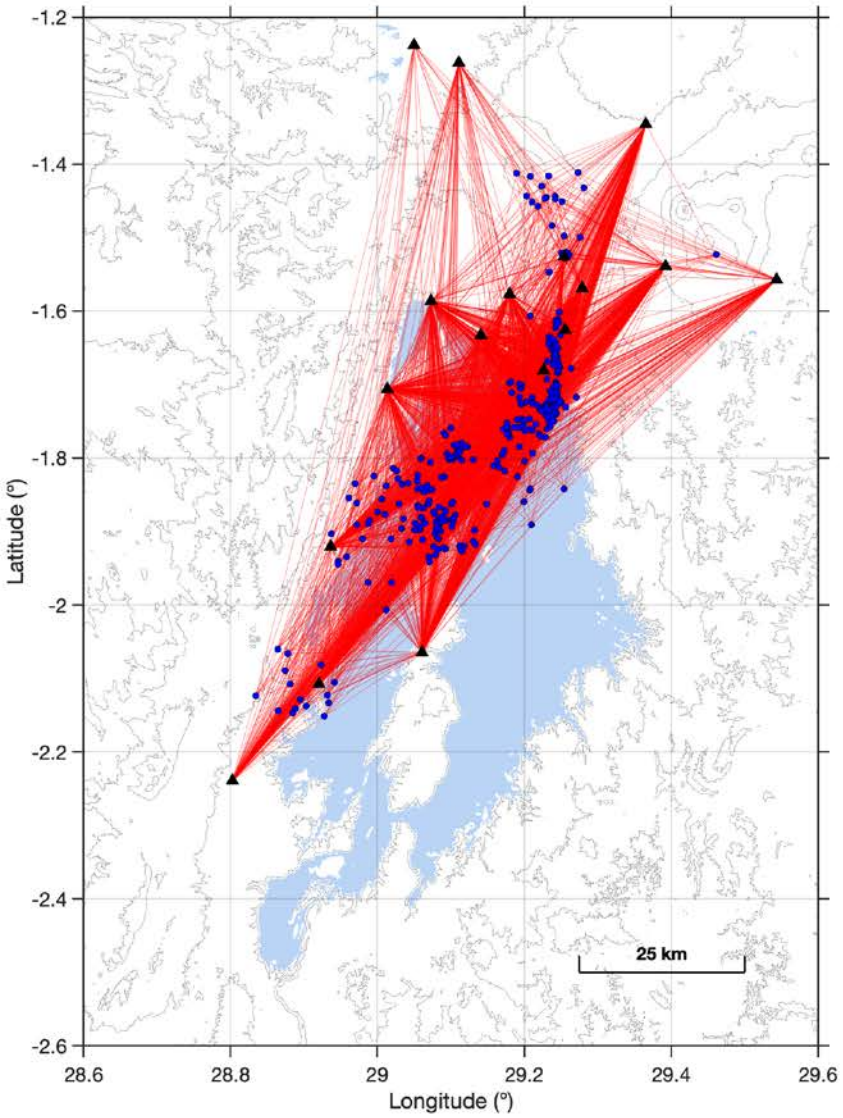
- wave velocities are obtained from a constant VP /VS ratio of 1.71

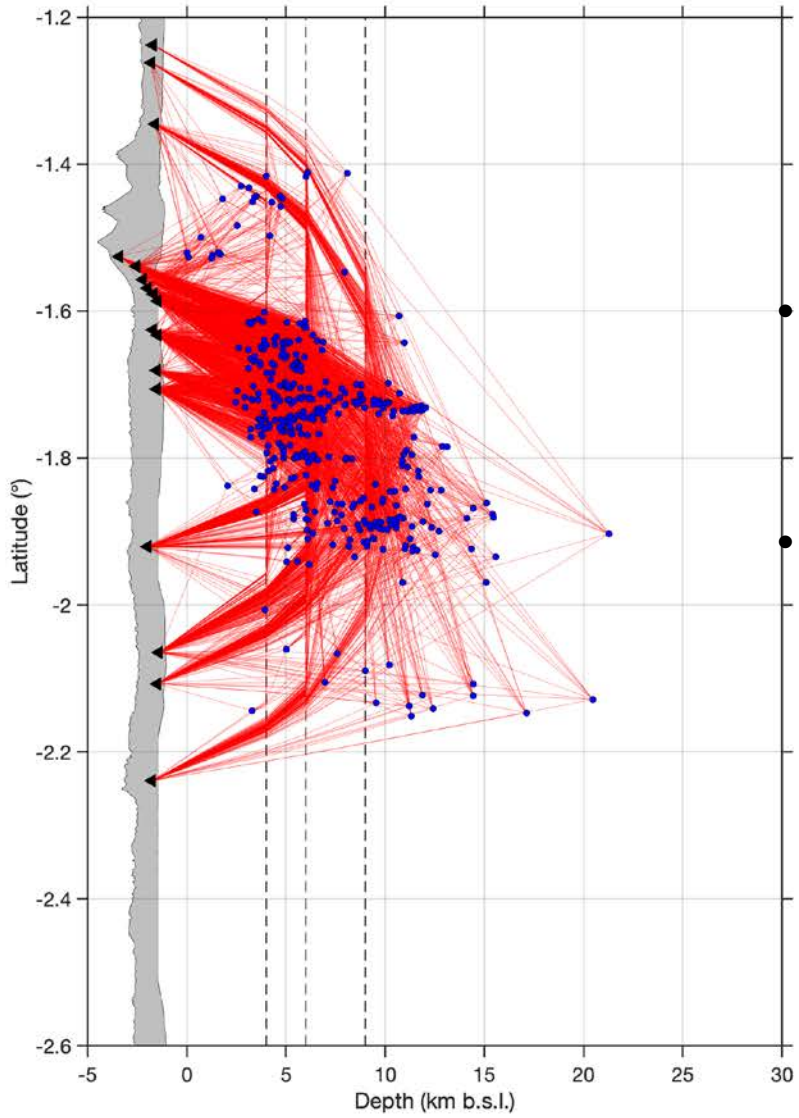
Top of layer(km)	P-wave velocity (km/s)	P-wave velocity (km/s)
0	5,35	3,13
4	5,88	3,44
6	6,14	3,59
9	6,23	3,64

P2. Seismological model and seismicity patterns

1D Velocity model

Kivu 1D: A new local minimum model



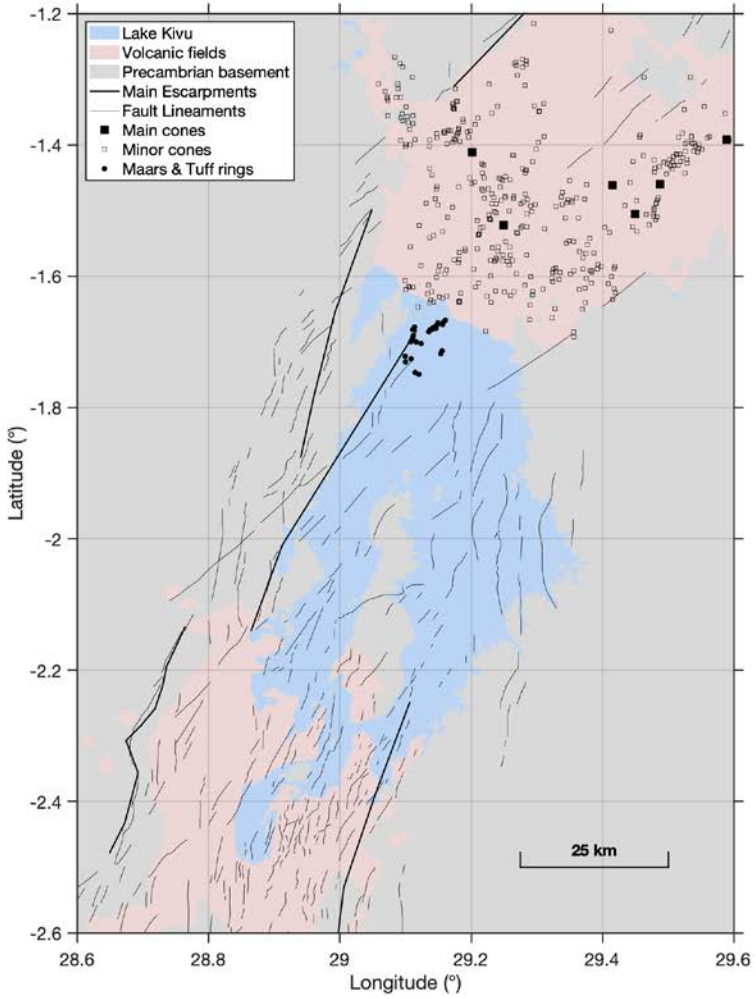


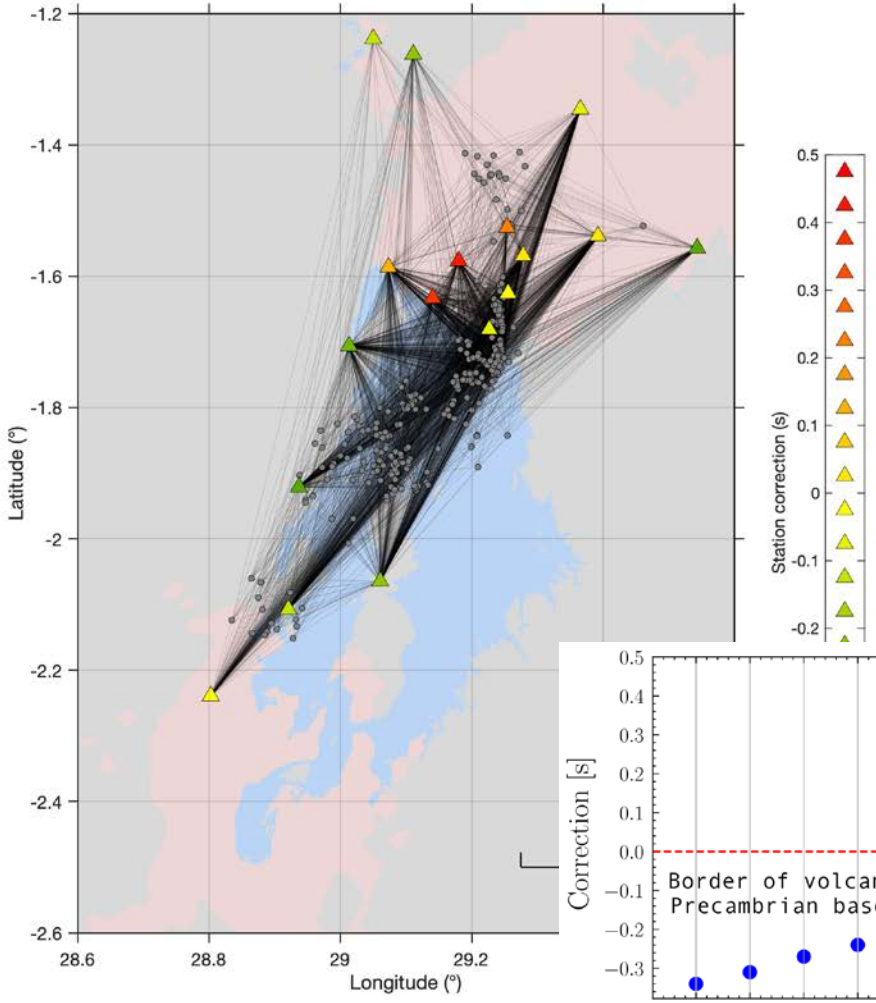
- The near vertical-incidence ray paths at shallowest depths do not uniformly sample the whole region,
- Local site effects may also be significant: determination of station correction terms

P2. Seismological model and seismicity patterns

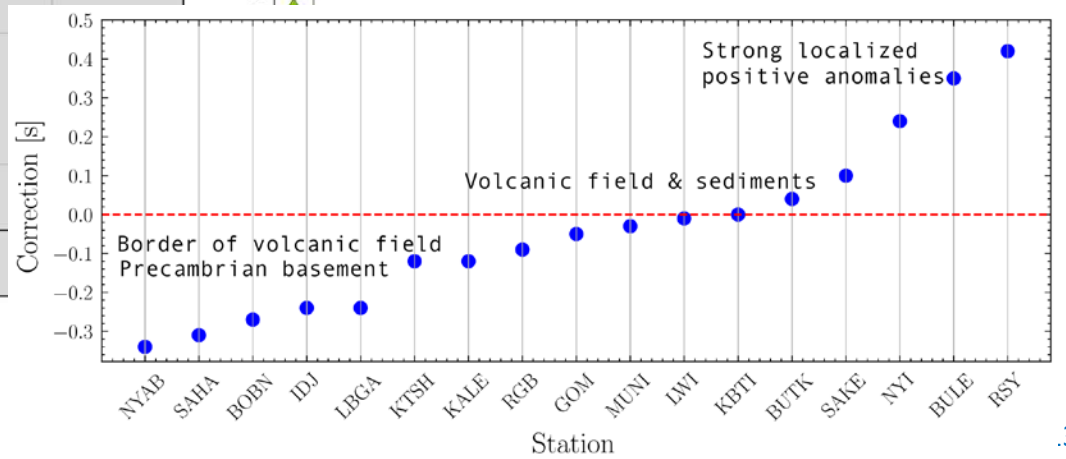
1D Velocity model

Determination of station correction terms





The delays associated to the known geological features make sense. The positive and near zero anomalies (i.e., lower velocity zones) are associated with stations located in the volcanic fields. All stations installed "off-rift" on the Precambrian rocks or at the border of the volcanic provinces are associated with negative anomalies

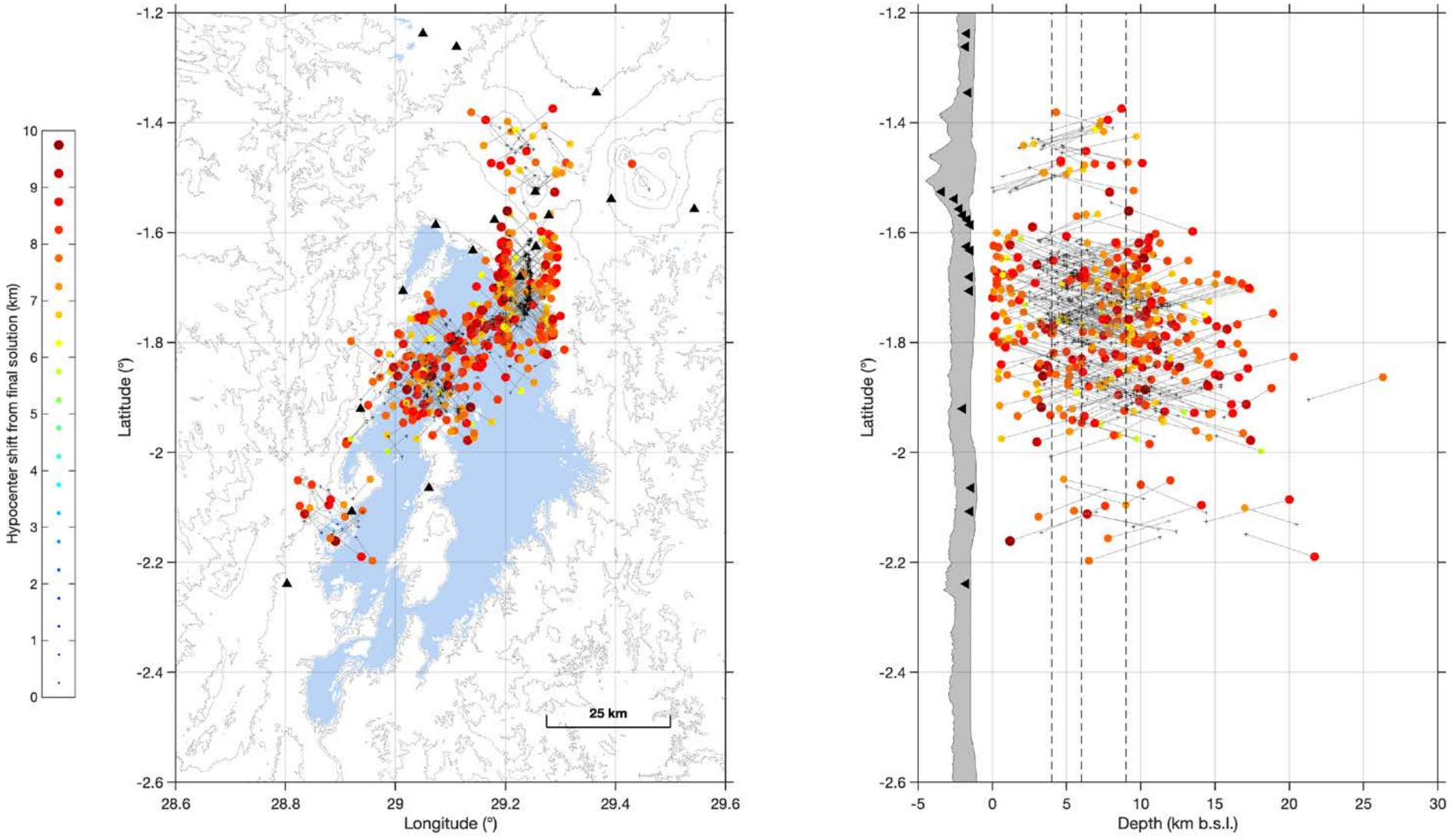


P2. Seismological model and seismicity patterns

1D Velocity model

Evaluation of model's stability

Random shift in horizontal and vertical directions

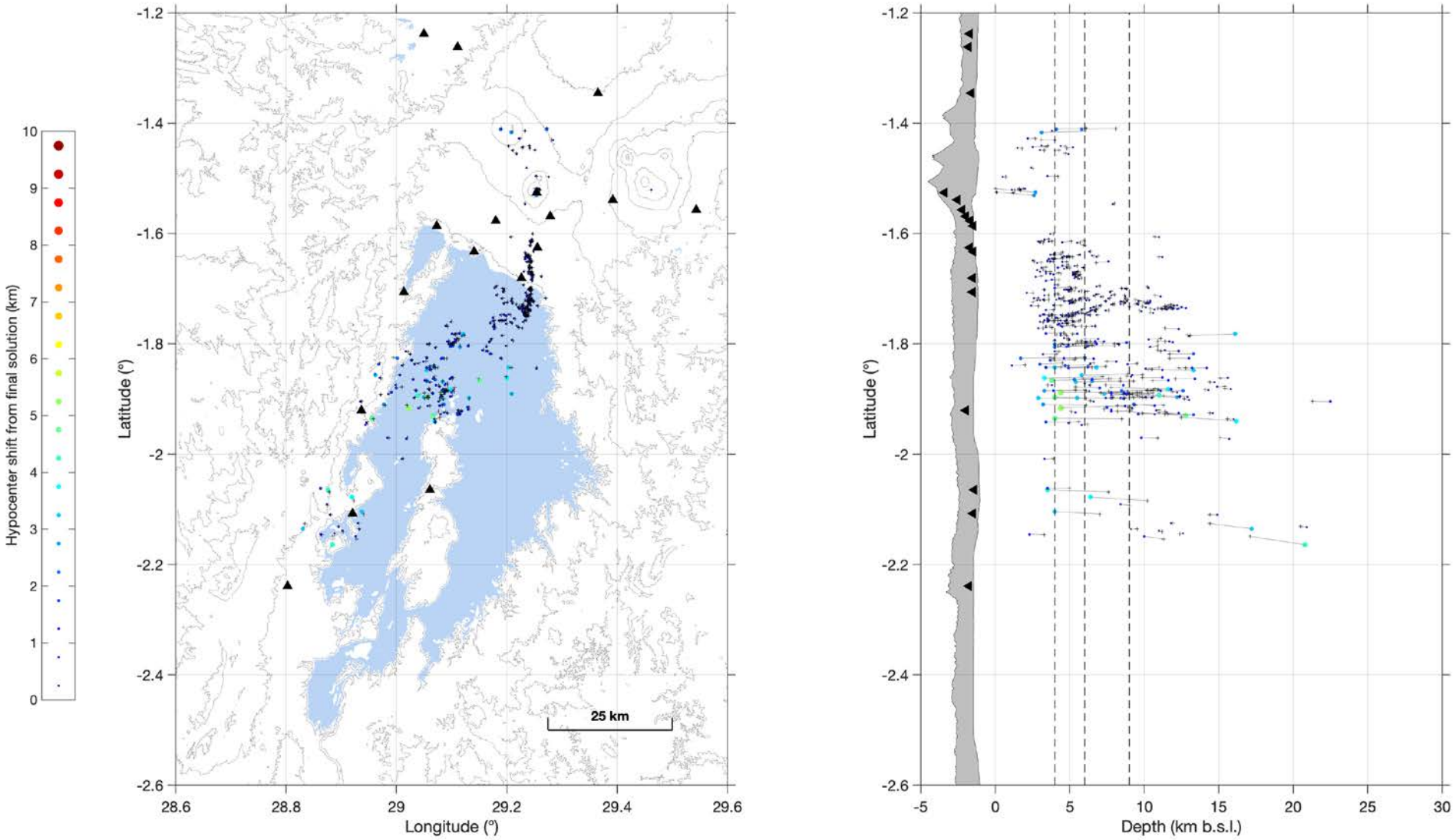


P2. Seismological model and seismicity patterns

1D Velocity model

Evaluation of model's stability

Event relocation after shifting



P2. Seismological model and seismicity patterns

1D Velocity model

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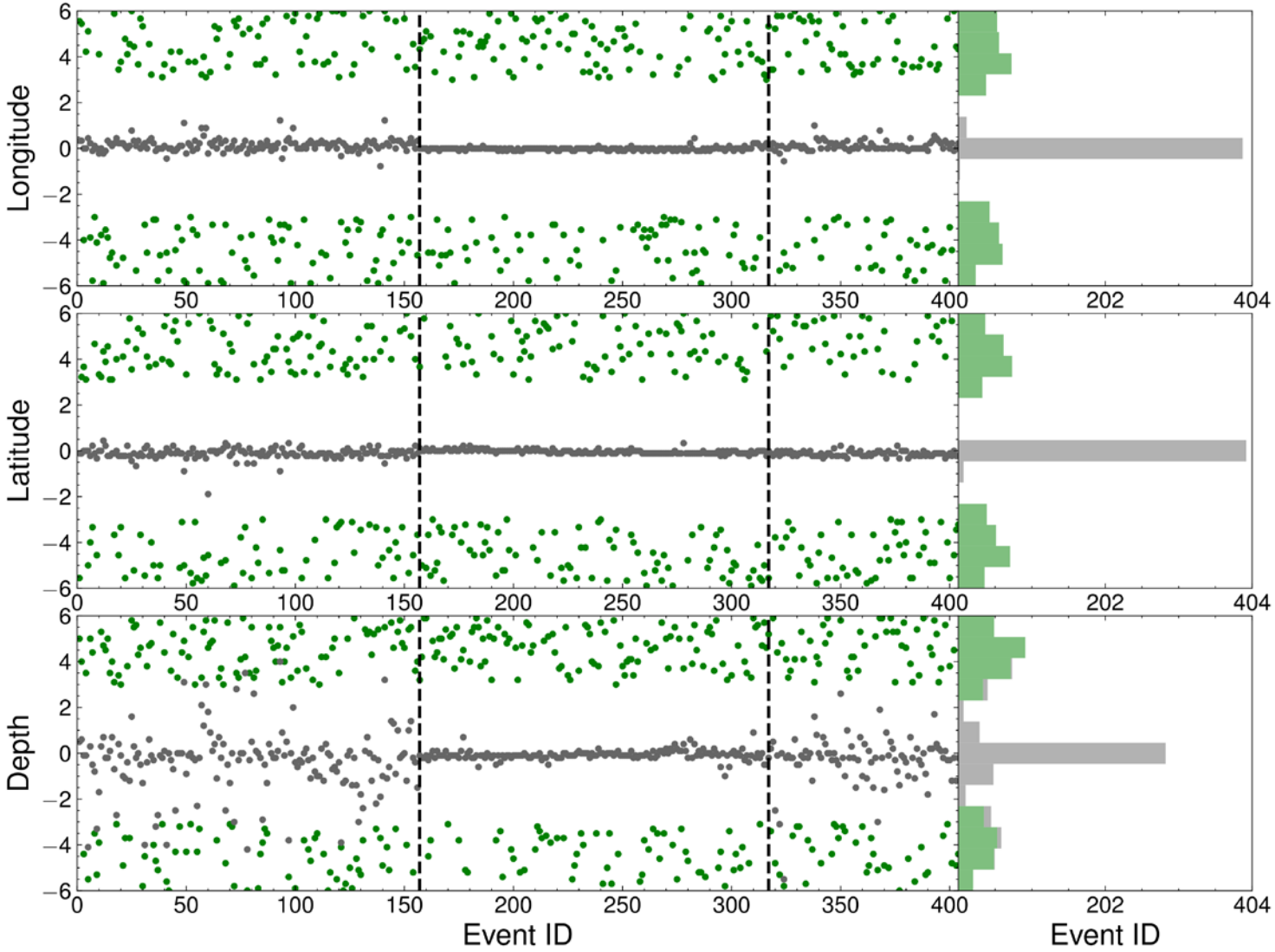
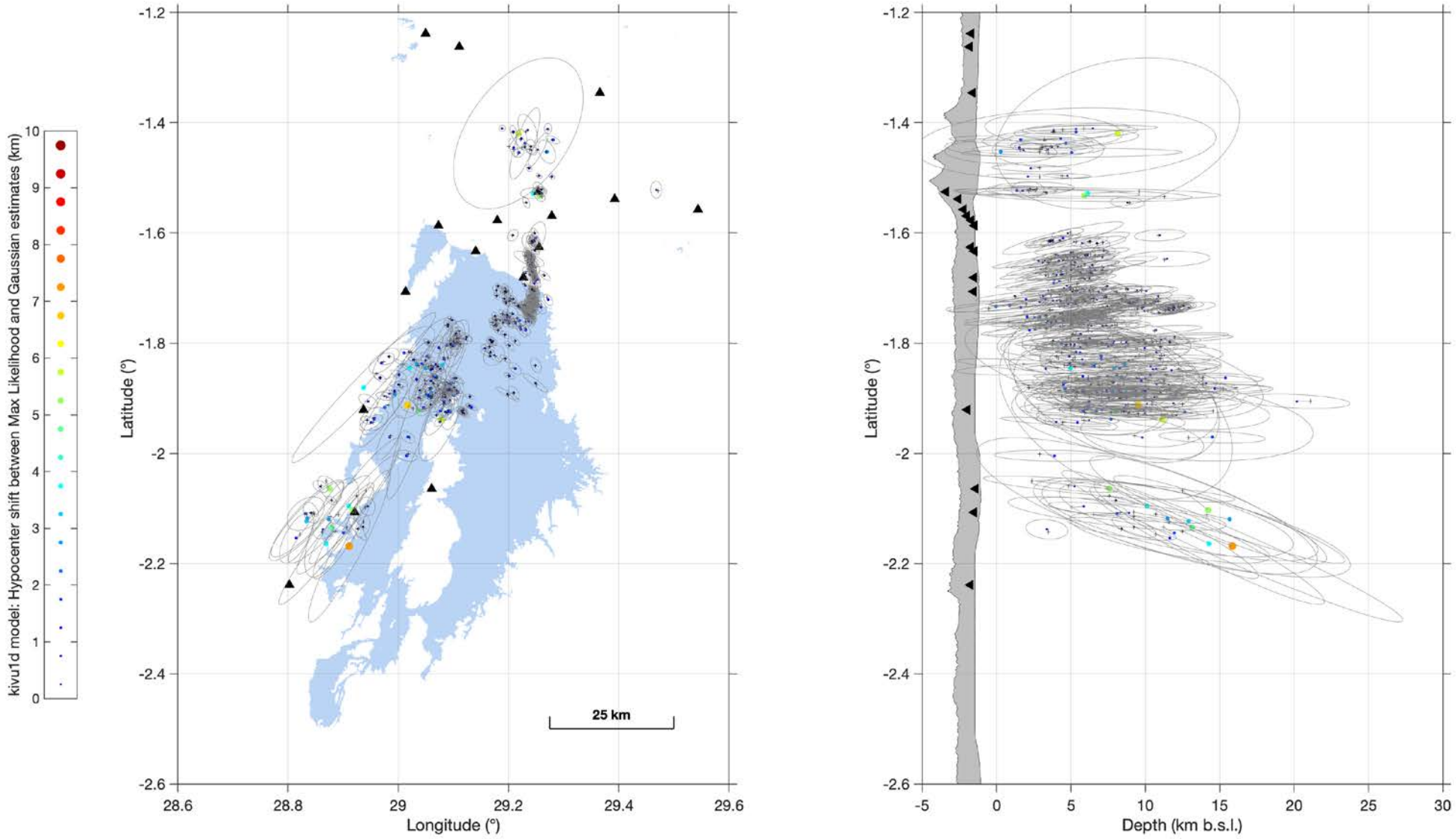


- The error in depth is less than 2 km for about 95% of the events. It is also noteworthy that events associated with the 2021 Nyiragongo eruption are best retrieved
- These are events located well within the network with numerous good quality observations for each of them.

P2. Seismological model and seismicity patterns

1D Velocity model

Comparative analysis between the former routine model and the new 1D minimum model



P2. Seismological model and seismicity patterns

1D Velocity model

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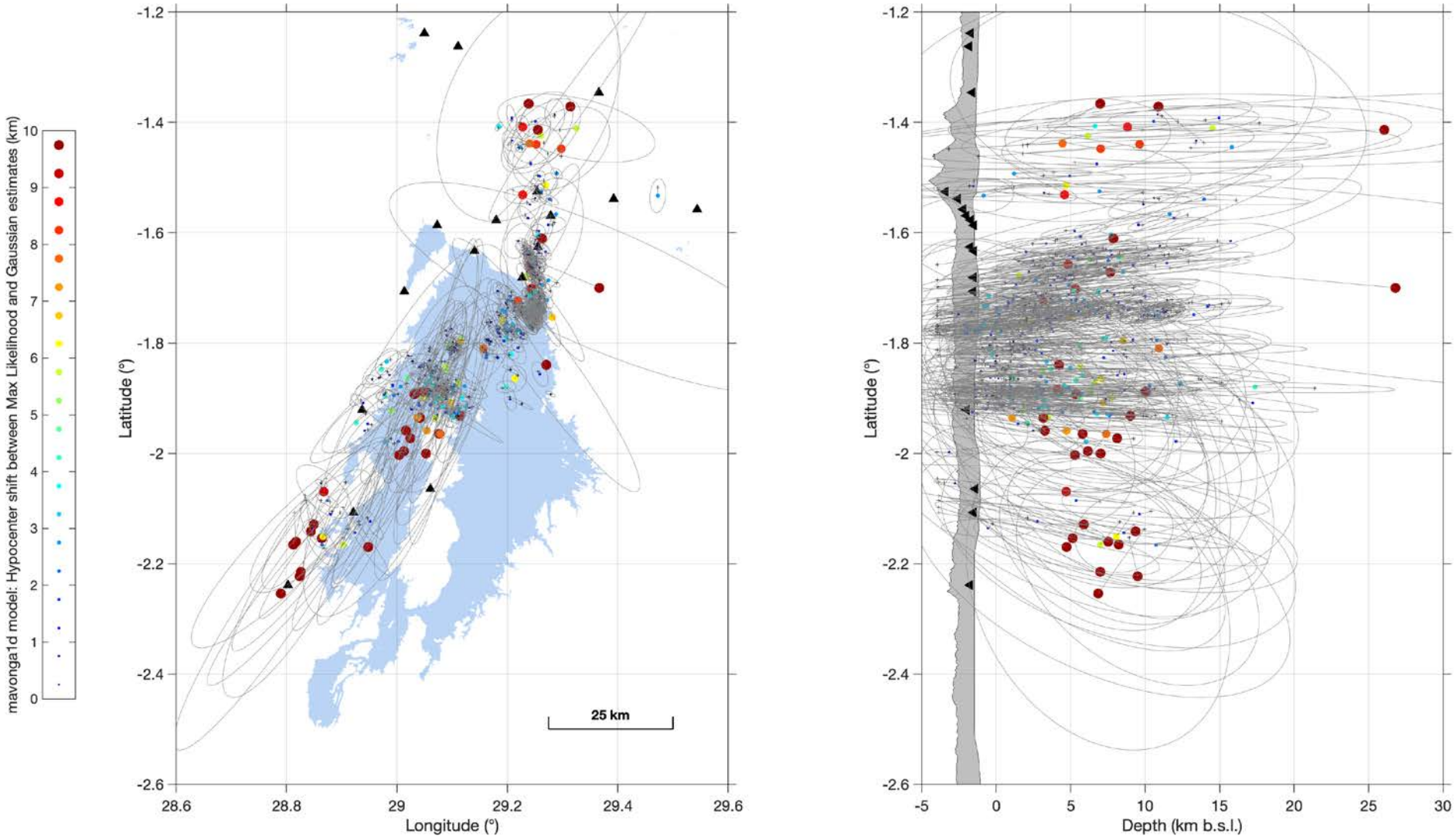
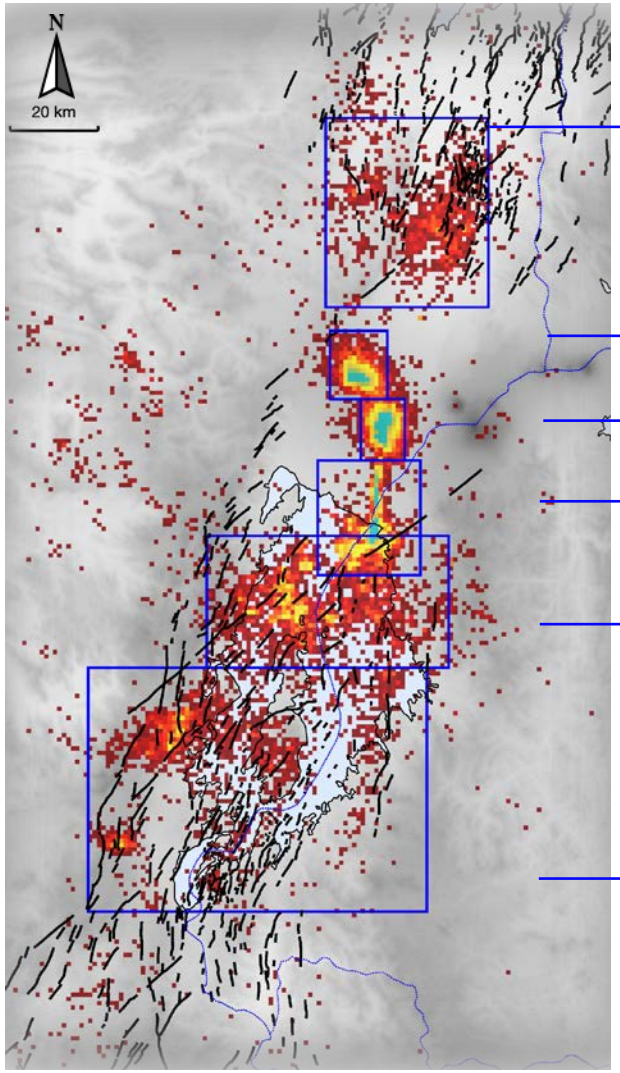
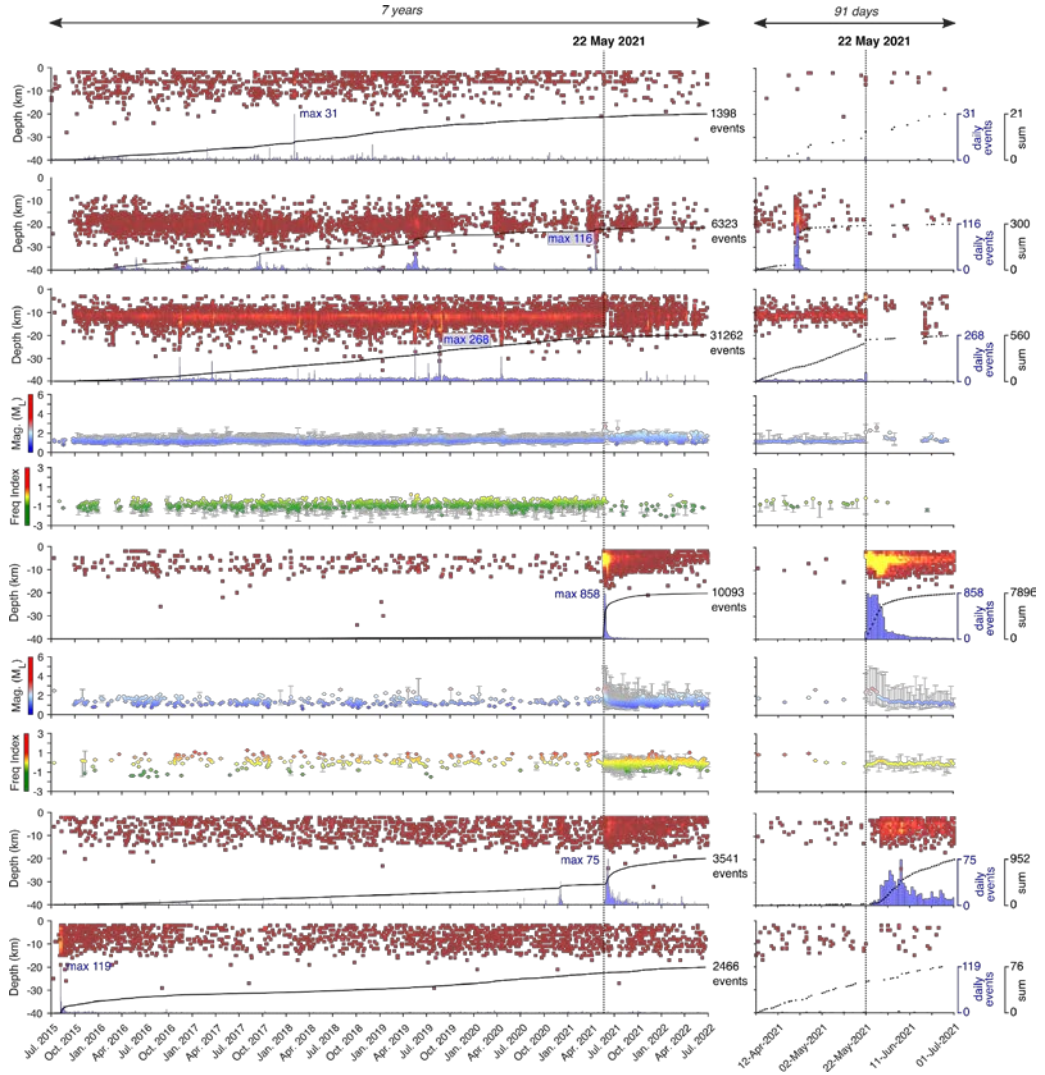


P2. Seismological model and seismicity patterns

1D Velocity model

Next: Volcanic and tectonic seismicity patterns (2015-2022)





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