Automatic full waveform-based monitoring of induced microseismicity at Garpenberg mine, Sweden

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NEW BOLIDEN

Contents

Motivation

https://www.npr.org/2014/11/12/363058646/coal-mines-keep-operating-despite-injuries-violations-and-millions-in-fines

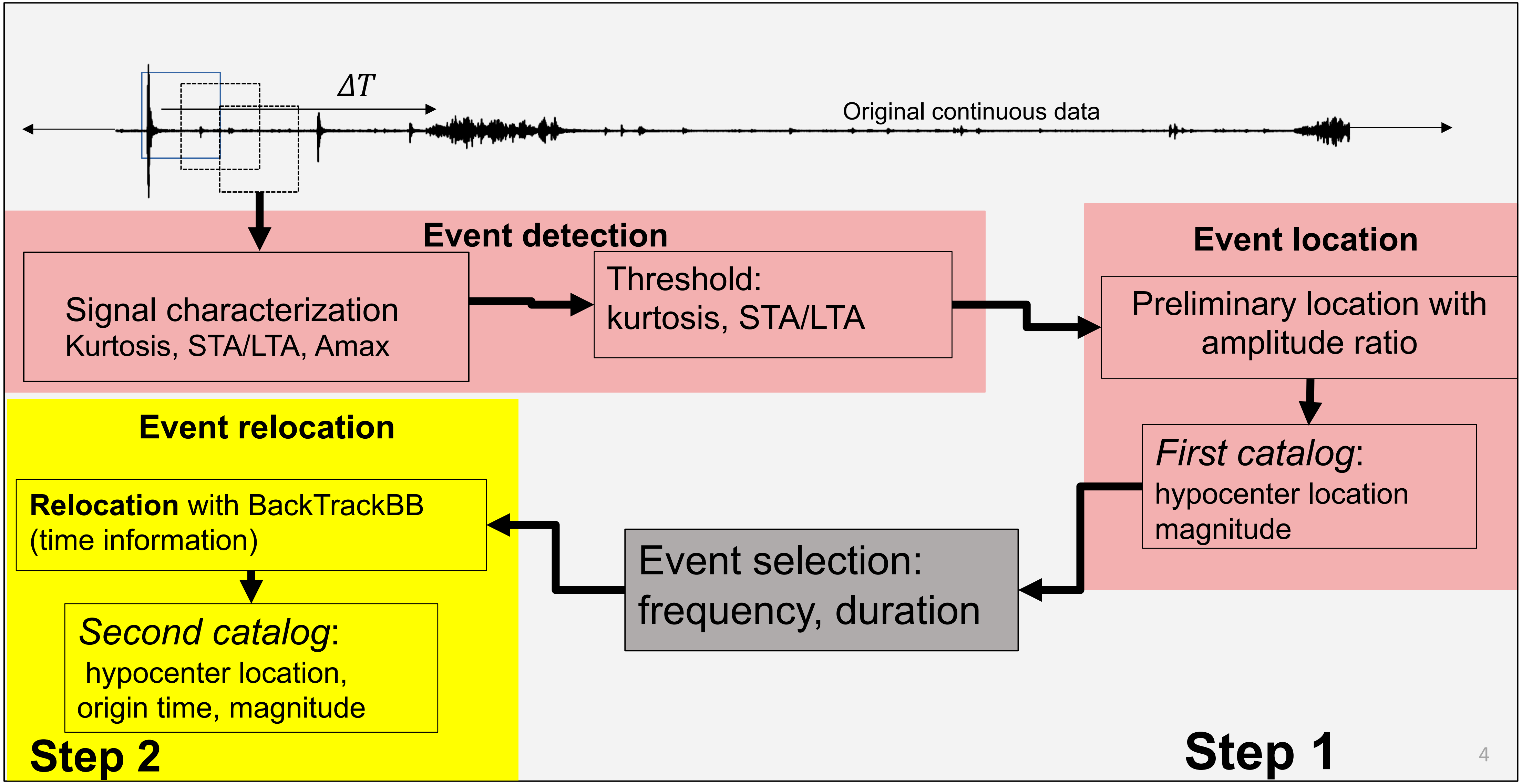
- Real-time monitoring is important:
  - Mitigating rock burst hazards.
  - Identifying rock mass instability to increase the safety of the workers.
  - Most of the methods are applied in natural seismicity.

- Key challenge of real-time microseismic monitoring:
  - Very low seismic magnitude (M < 0).
  - High anthropogenic noise.

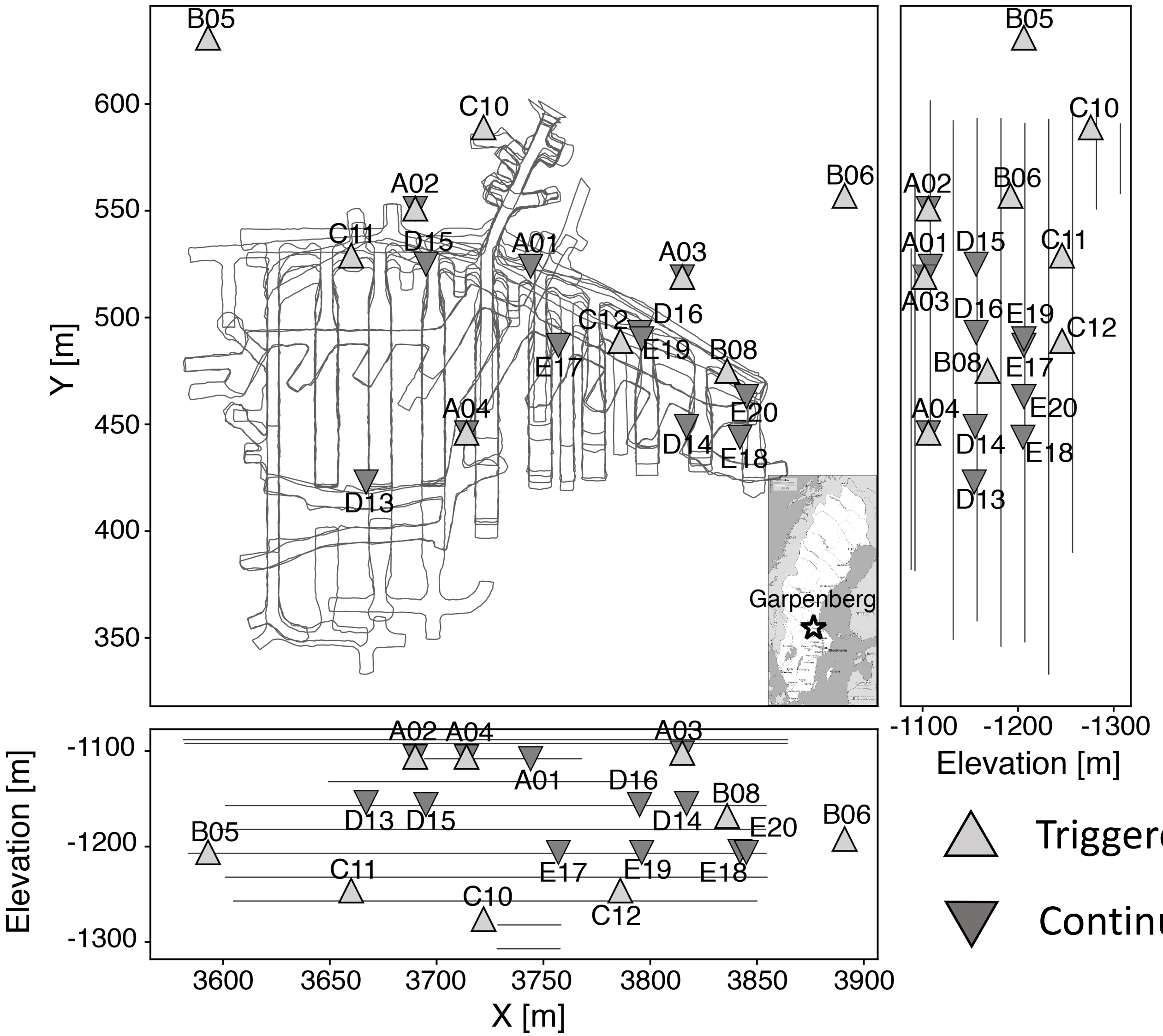
http://www.mineaccidents.com.au/mine-accident/68/appin-colliery-1979

Motivation

(Palgunadi et al., submitted)

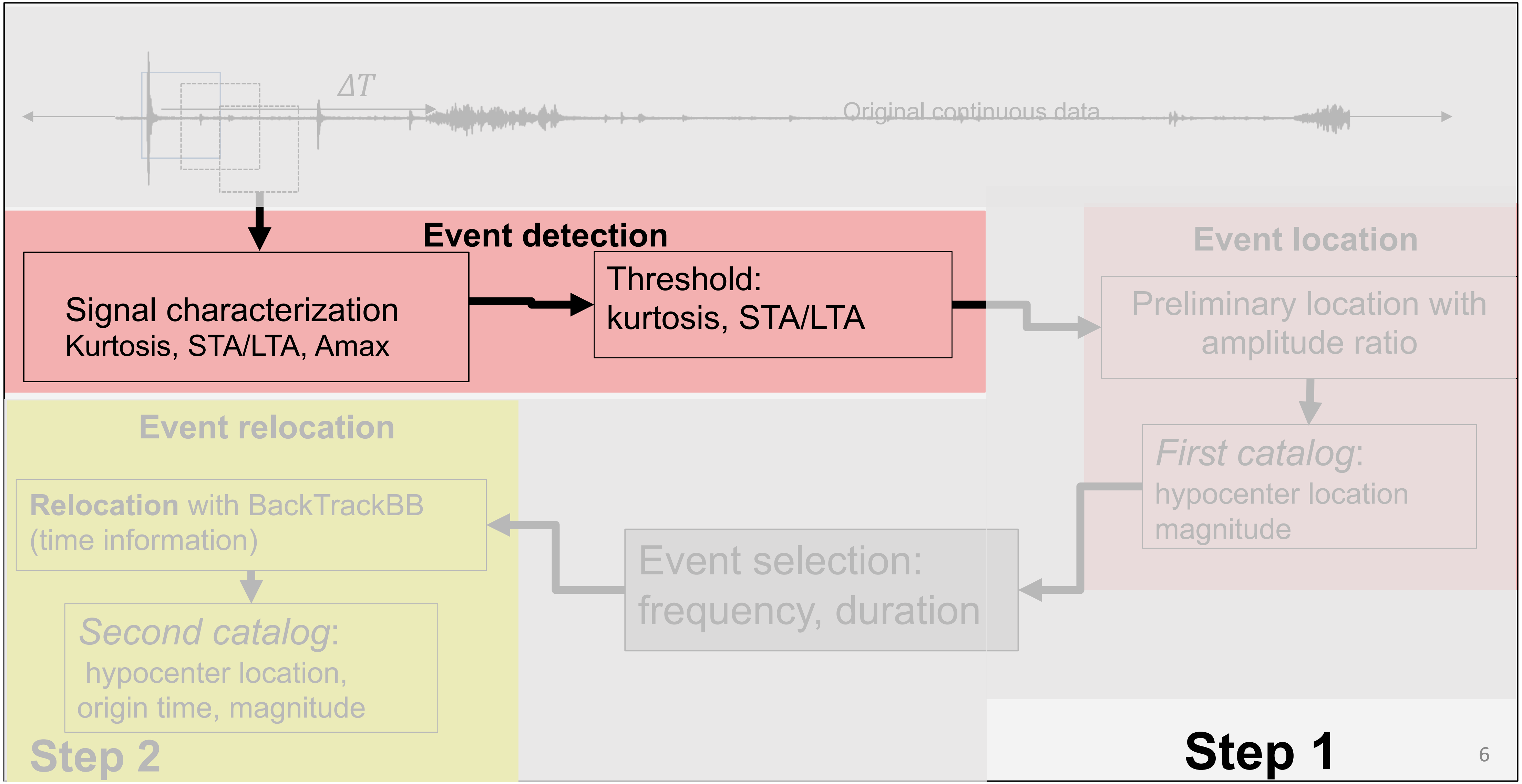


Data description

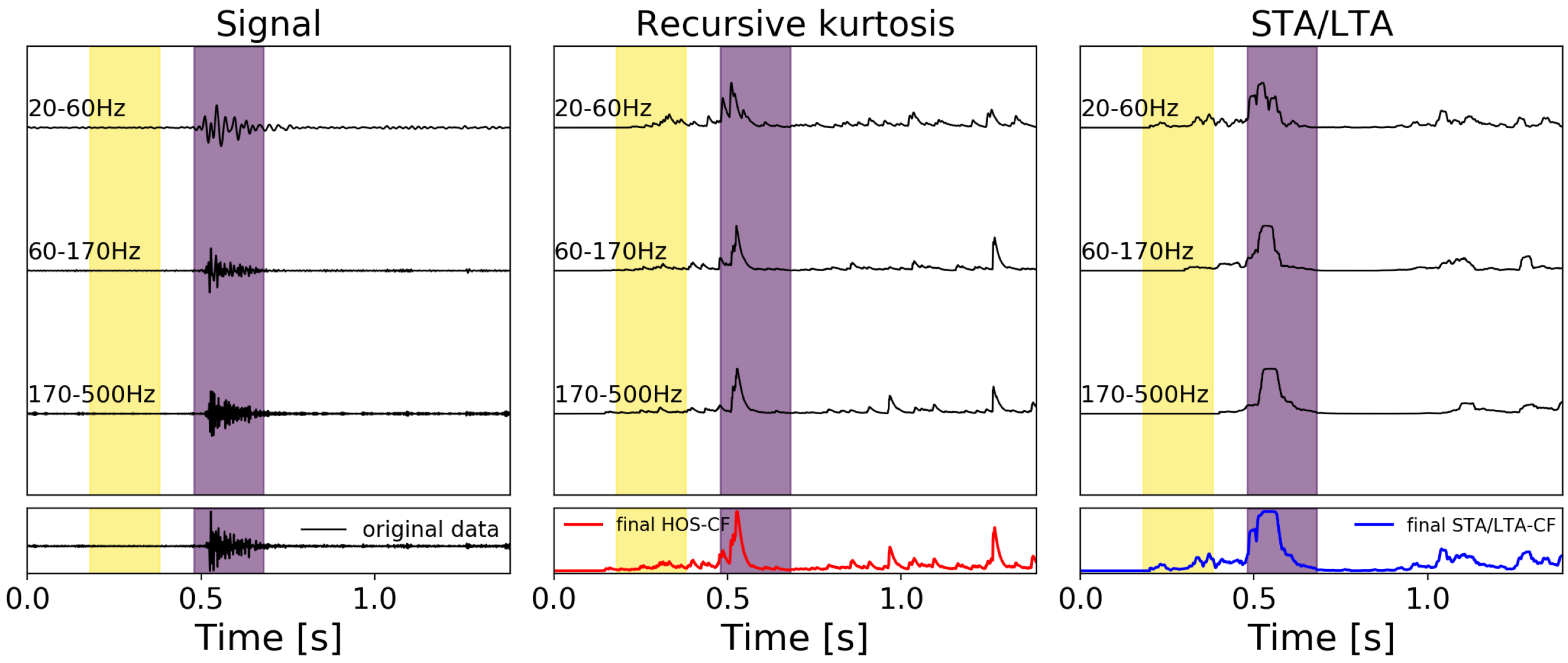


- Map of Boliden Garpenberg deep ore-mine area and station configurations.
- 1km deep.
- Development by blasting.
- 8 kHz sampling rate.

Event detection



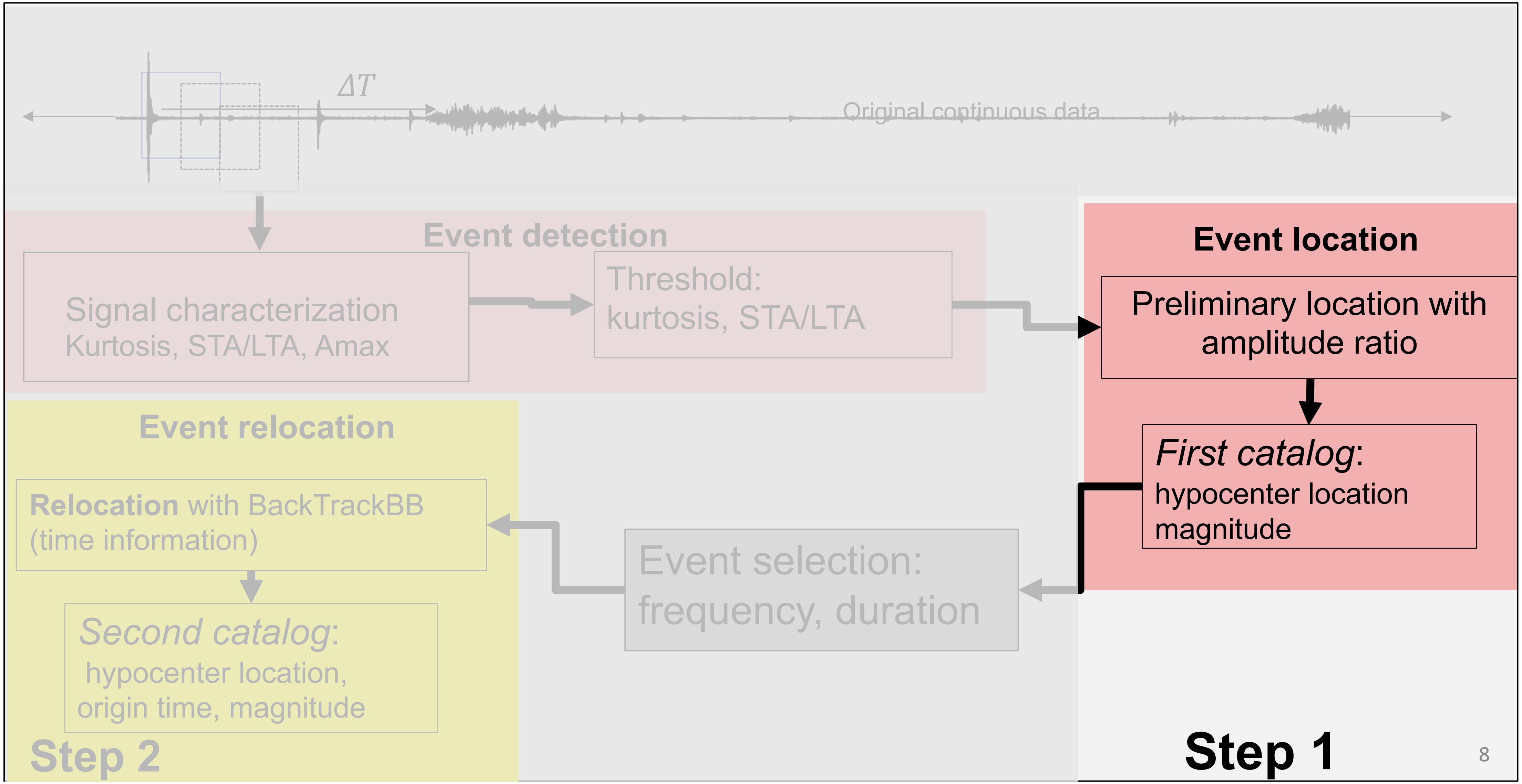
Signal transformation and Multiband-frequency filter



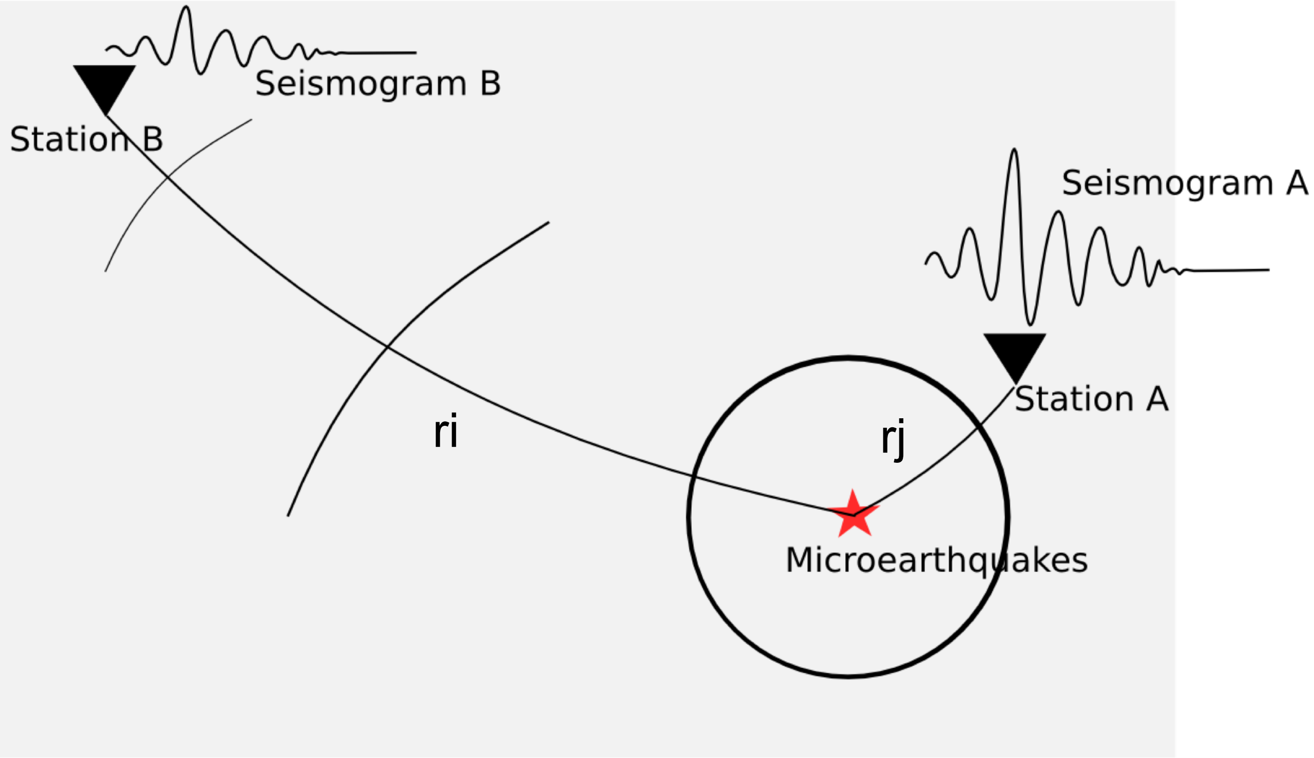
$$CF(t_i) = max\{CF(t_i; f)\}, f \in [f_{20-60Hz}, f_{60-170Hz}, f_{170-500Hz}]$$

- Using STA/LTA and recursive kurtosis.
- Time frequency decomposition allows one to obtain access to the impulsive transient signal that tends to appear in a narrow frequency band.

Event location (training data)



Location using amplitude ratios



$$A(f) = S(f) \cdot A_0(E) \cdot \frac{1}{r^n} \cdot \exp\left(\frac{-\pi f_k r}{Q \cdot V_S}\right), \quad f \in [f_{low}, f_{med}, f_{hi}]$$

Site amplification

Geometrical spreading

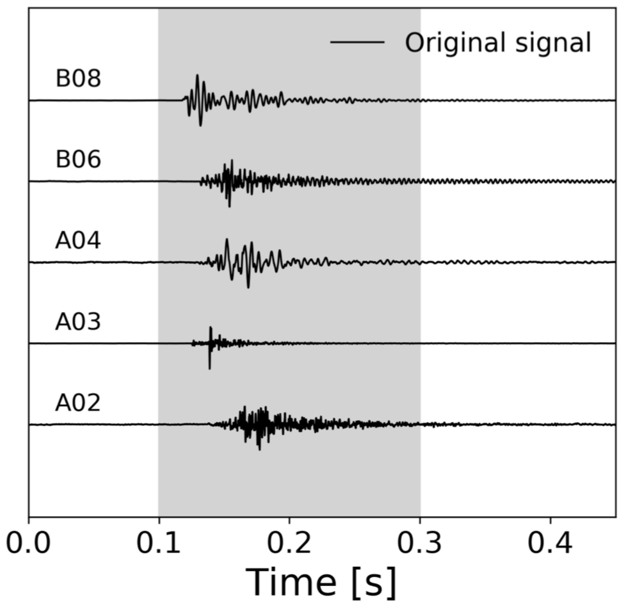
attenuation

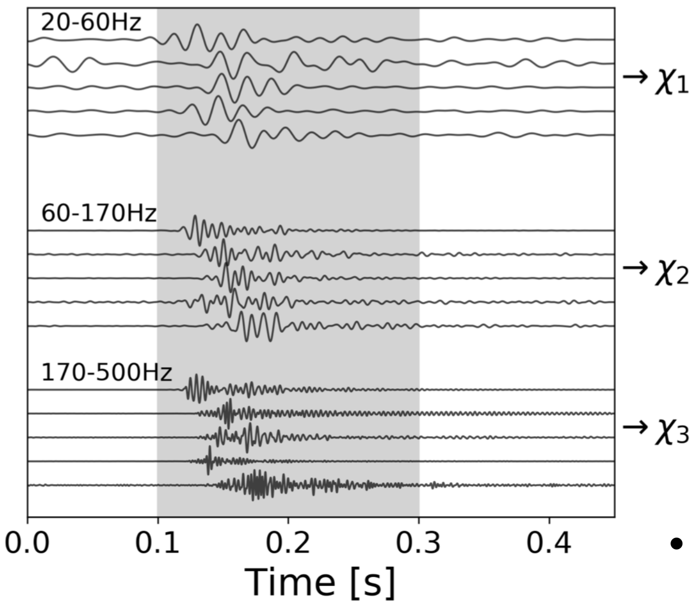
$$\log_{10}(R_{ij}) = \log_{10}\left(\frac{A_i(f)}{A_j(f)} \cdot \frac{S_j(f)}{S_i(f)}\right) = n \cdot \log_{10}\left(\frac{r_j}{r_i}\right) - \frac{\pi f_k (r_i - r_j)}{Q \cdot V_S} \cdot \log_{10}(\exp(1))$$

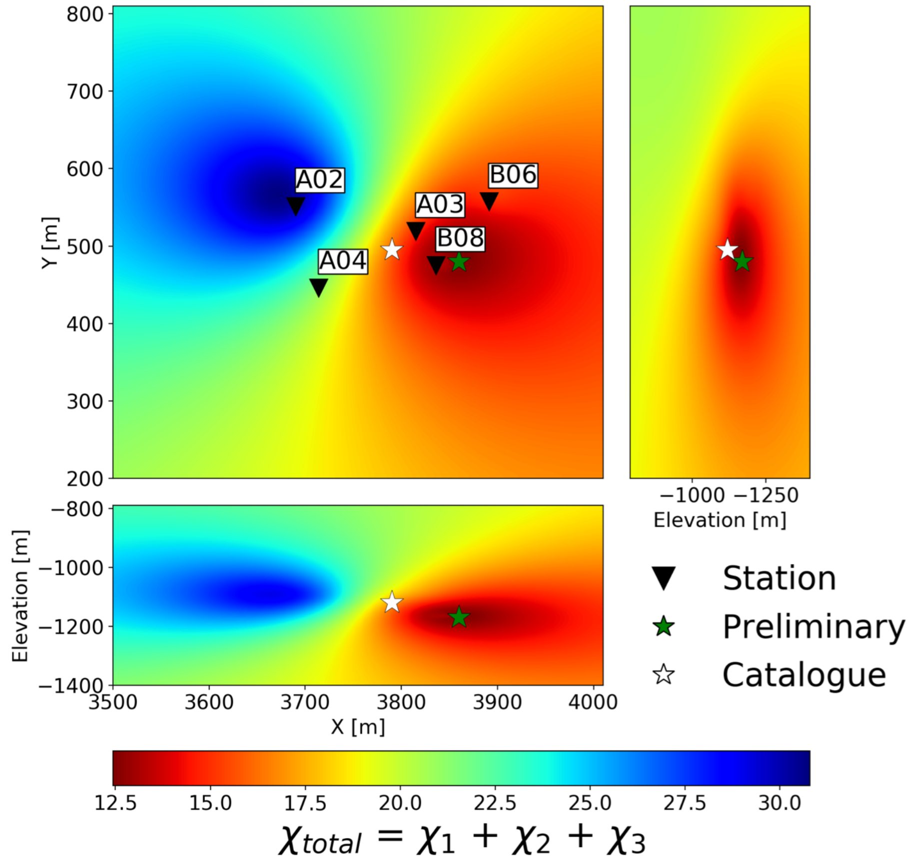
Location using amplitude ratios

$$R_{calc}^{ij} = n \cdot log\left(\frac{r_j}{r_i}\right) - \frac{\pi \cdot f_k}{Q \cdot V_S} \cdot (r_i - r_j) \cdot log(e)$$

$$\chi = \frac{1}{N_{pairs}} \sum_{ij}^{N_{pairs}} \sum_{k}^{\xi} \frac{\left(R_{obs}^{ij} - R_{calc}^{ij}(x_k, y_k, z_k)\right)^2}{\sigma}$$

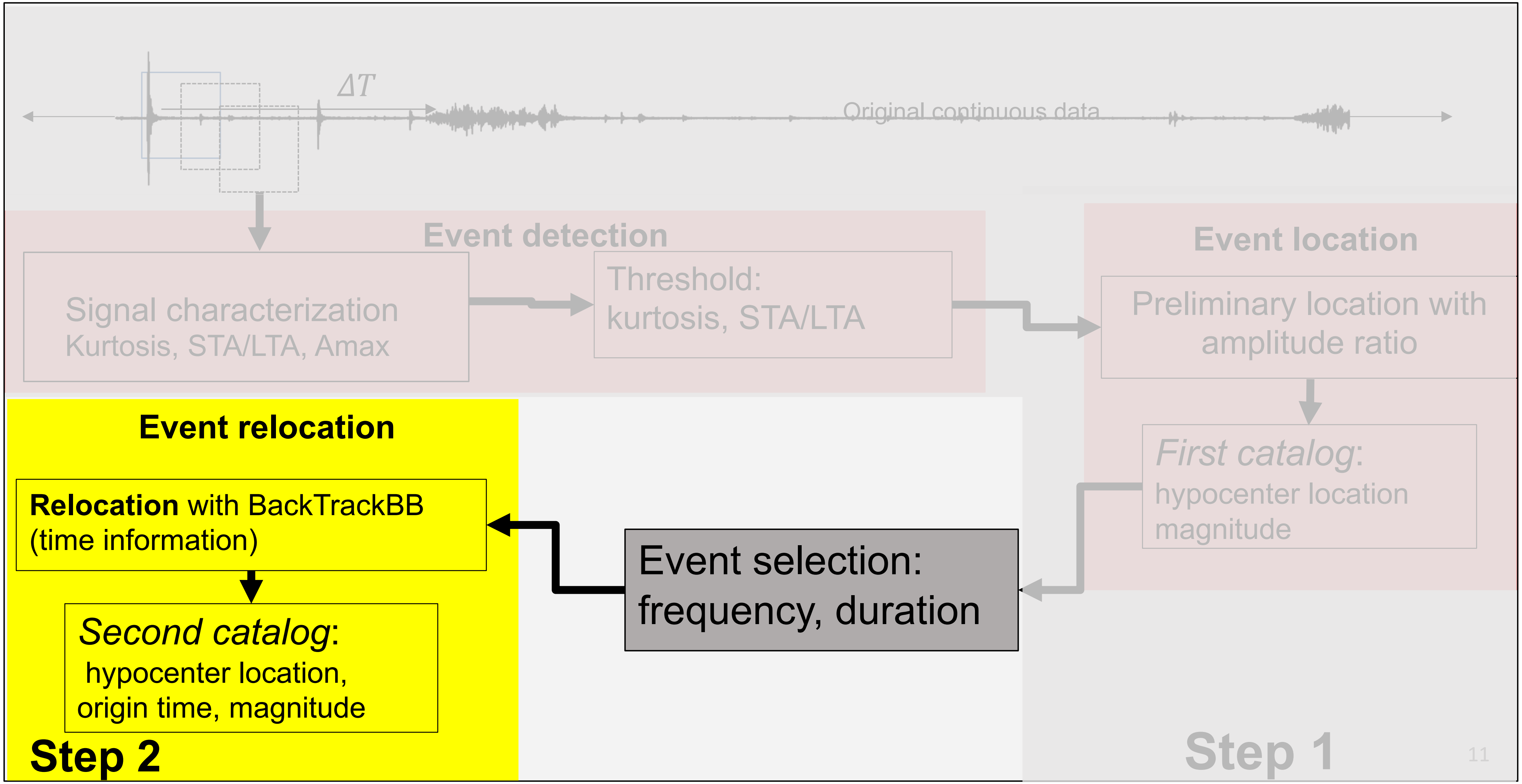




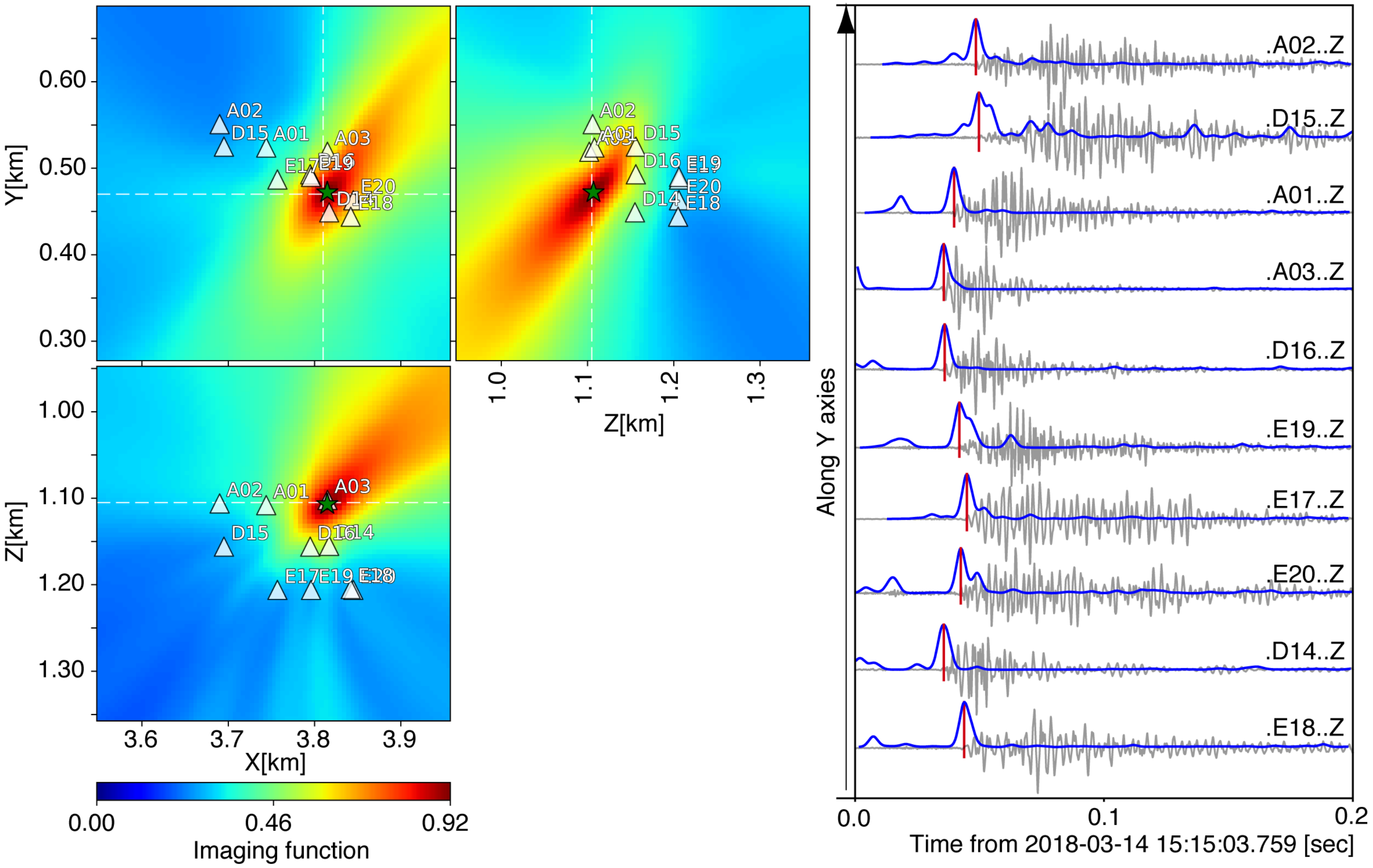


- **Least combined misfit function = hypocenter location.**

Event relocation (Step 2)



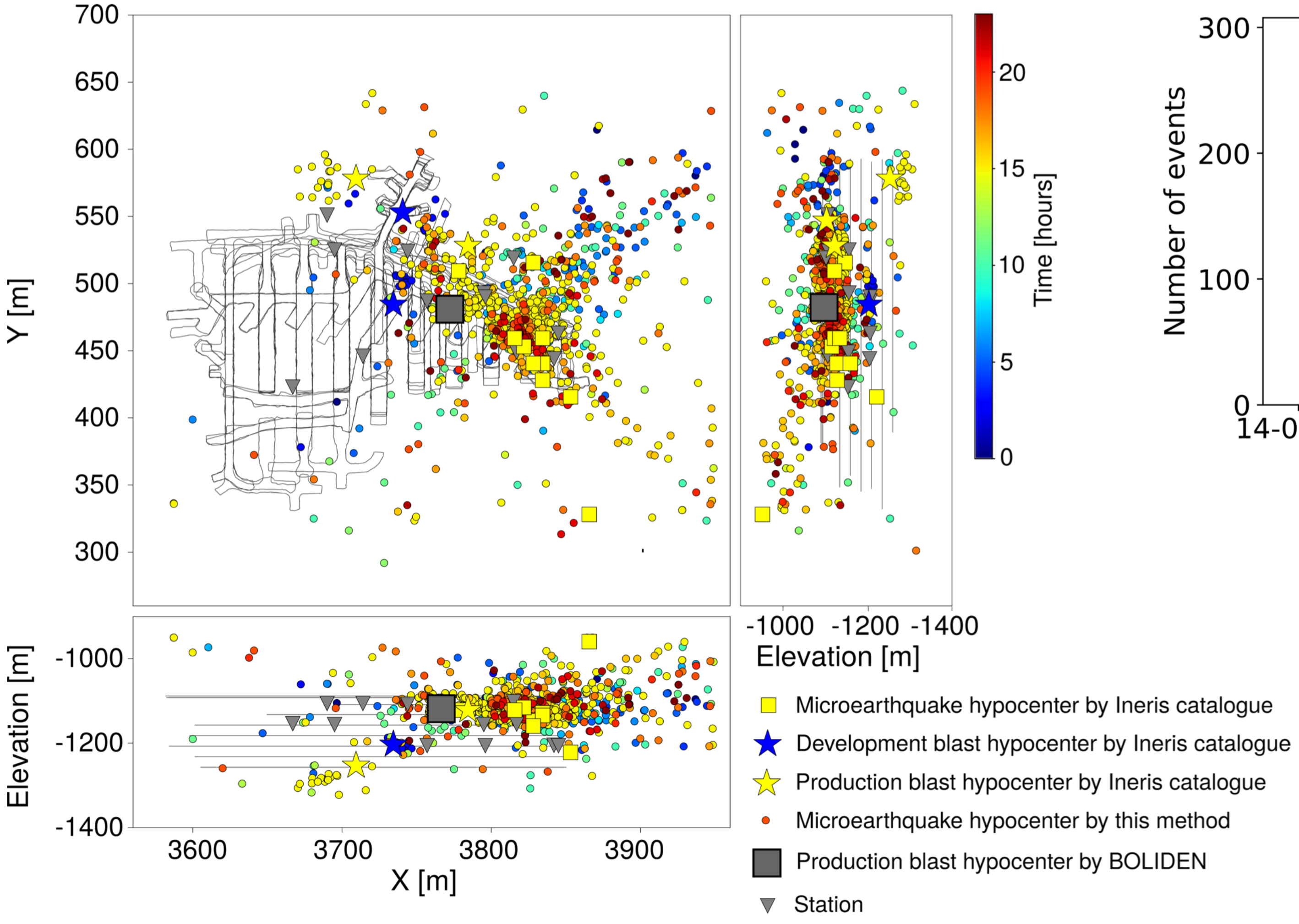
Relocation using BackTrackBB

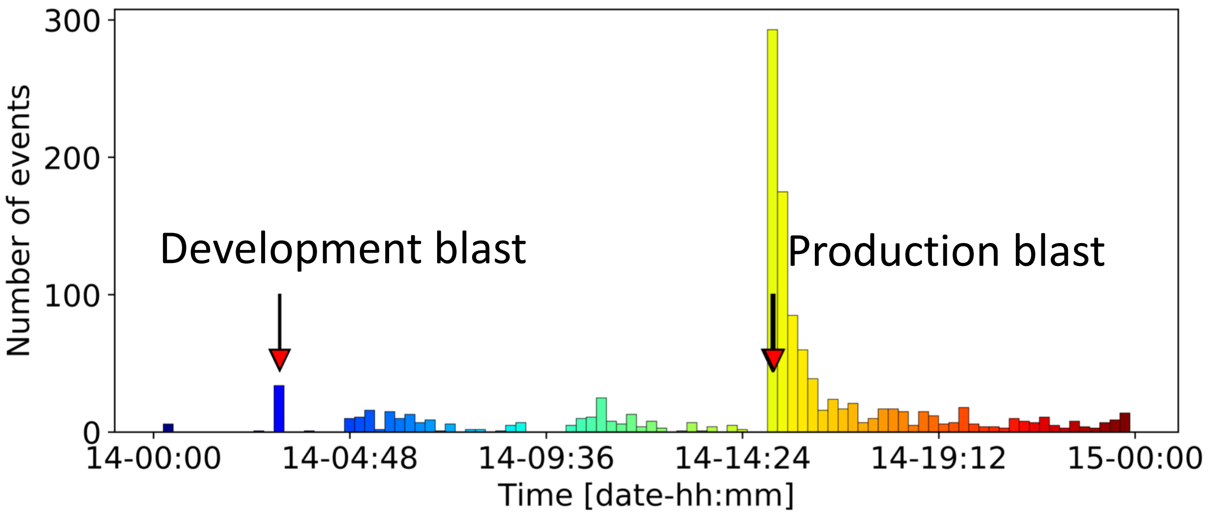


- BackTrackBB method:
  - ✓ Signal processing for detection and selection.
  - ✓ Back propagation.
  - ✓ Location: maximum value of the 3-D spatial likelihood imaging function.
  - ✓ Provide time-space information.

❑ Relocation from second step using BackTrackBB (Poiata et al. 2016 [GJI]).

Relocated events vs catalogue





- Well identified events: 1237.
- Catalogue: 22.

Conclusions

- Near real-time monitoring with high sampling rate can be implemented.
- This method provides more events.
- Can be used as daily assessment of mining activity.

➢ Challenges:

  ✓ Event classification -> Discussed in *Palgunadi et al. (submitted).*