Use of a seismo-acoustic array for local to near-regional quarry blasts monitoring

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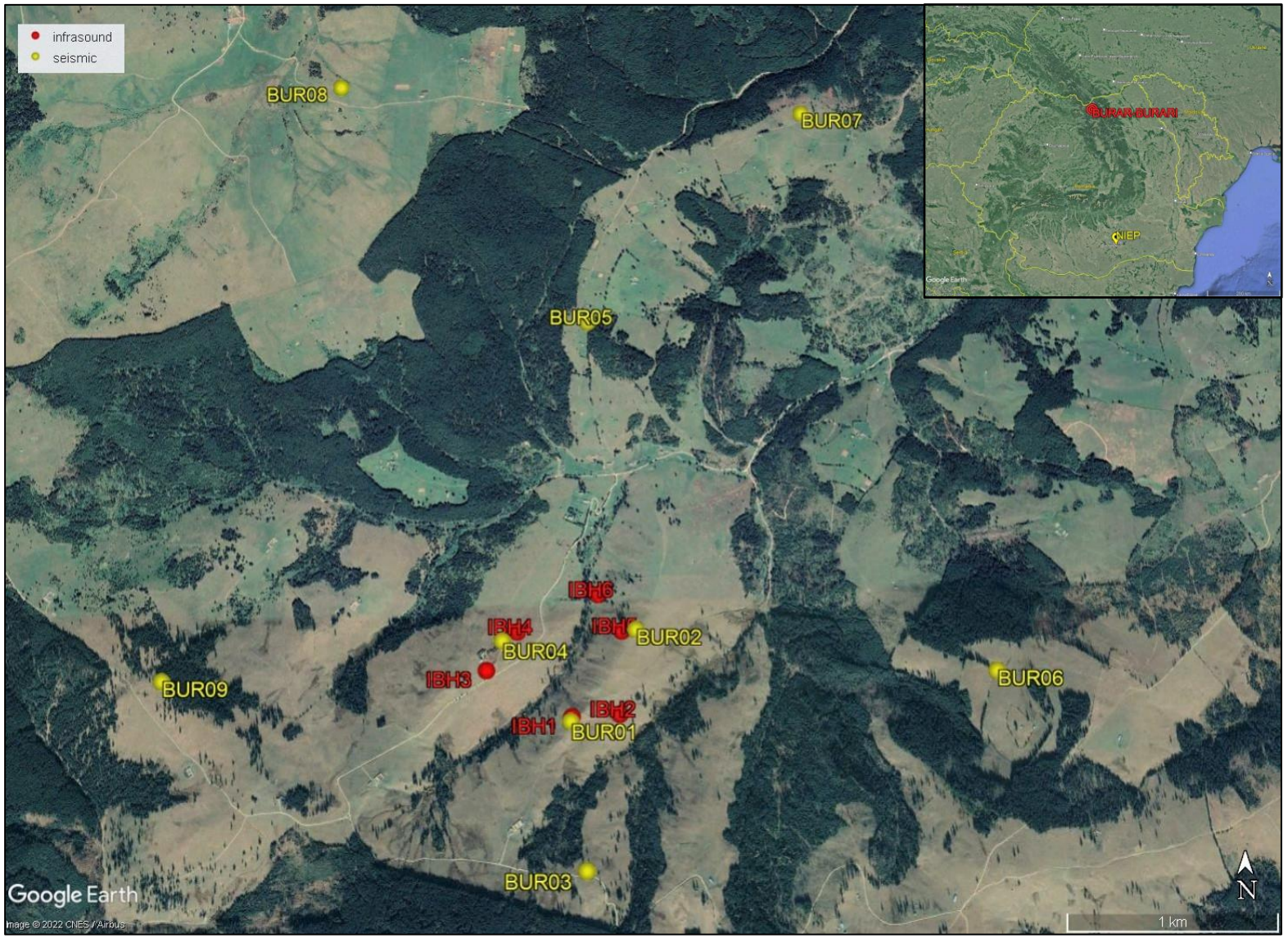
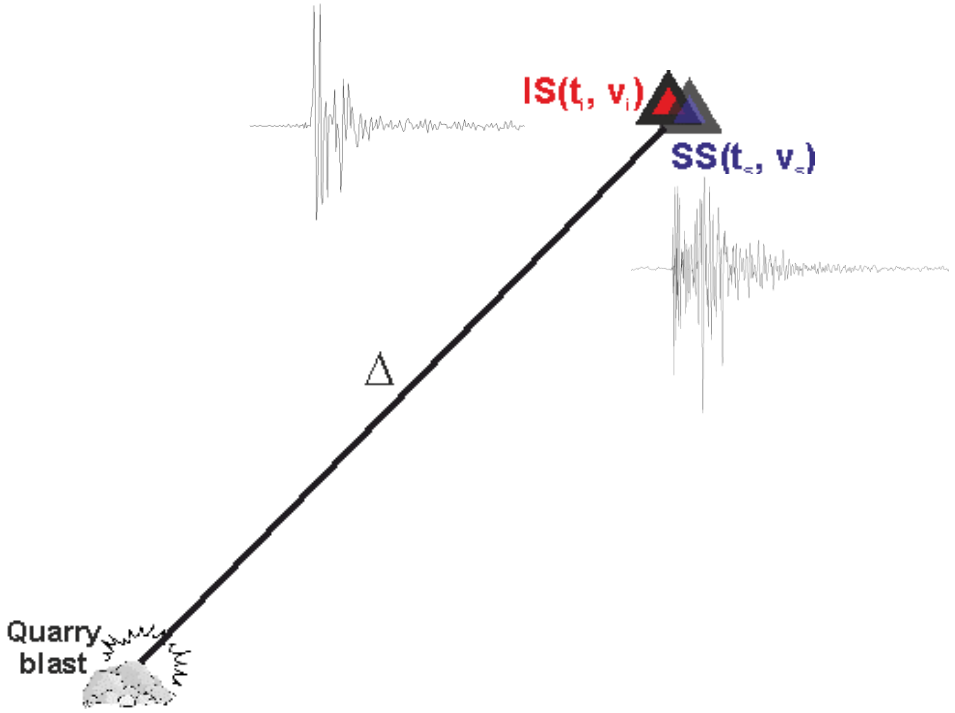
BURAR-BURARI seismo-acoustic array



- NIEP operates BURAR-BURARI seismo-acoustic array deployed in northern Romania under a joint effort with AFTAC (USA):
  - six infrasound sensors Hyperion IFS-5113 (0.7 km aperture)
  - nine SP borehole seismometers GS-21 (4.5 km aperture)
- Impulsive and short-duration signals, generated by repeating sources confined in certain directions, are frequently detected during daytime both by seismic and infrasonic sensors
- As a number of active quarries are located in the local to near-regional distance ranges, we assumed that many of the seismo-acoustic signals are generated by the surface blasts conducted in these sites

Identification of near-field quarries (1)

- Empirical method for identification of near-field quarries from blasts: associating the *seismic signal* (BAZ_s, t_s, v_s) with the *infrasonic arrival* (BAZ_i, t_i, v_i) based upon phase characterization (back azimuth, propagation time and trace velocity)
- Distance range within 5 – 50 km of the infrasound array: fastest infrasonic phases, i.e., direct or tropospheric (short distance and impulsive signals with quite large SNR could indicate the direct waves arrivals); for the most infrasonic arrivals generated by the near-surface blasts, the apparent acoustic speed is close to the sound speed at the array site
- Seismic surface type waves (Rayleigh and Love) are propagating along the Earth surface
- Seismo-acoustic signals: short duration (2 – 4 s), high frequency content (above 2 Hz), stable azimuth, quite stable trace velocity
- Distance (Δ) is calculated from the time difference (t_{diff}) between seismic and infrasonic arrivals (BURAR and BURARI)



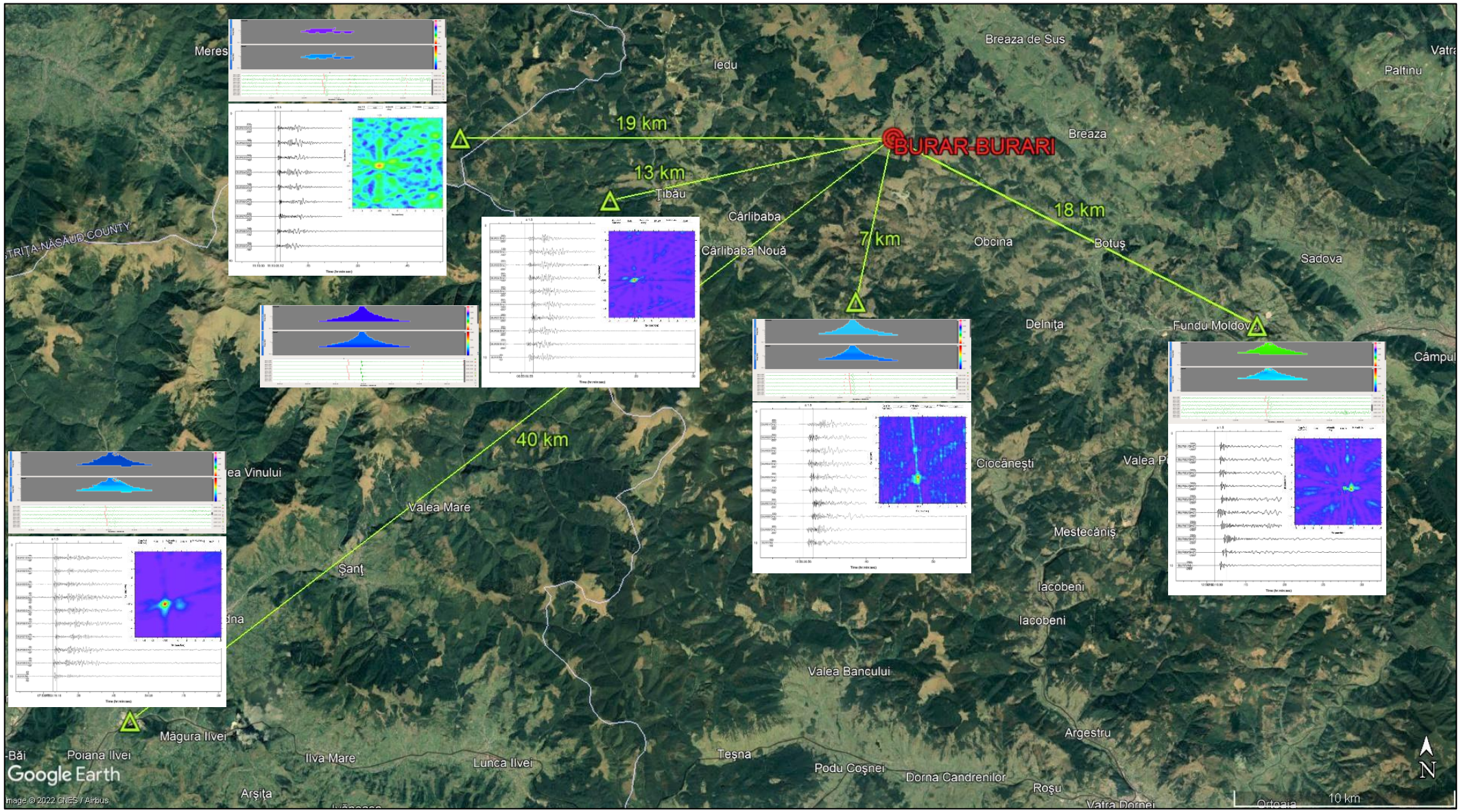
$$\Delta = t_s * v_s \qquad \Delta = t_i * v_i \qquad t_i = t_s + t_{diff}$$

$$t_s = \frac{t_{diff} * v_i}{v_s - v_i}$$

$$\Delta = v_s * \frac{t_{diff} * v_i}{v_s - v_i}$$

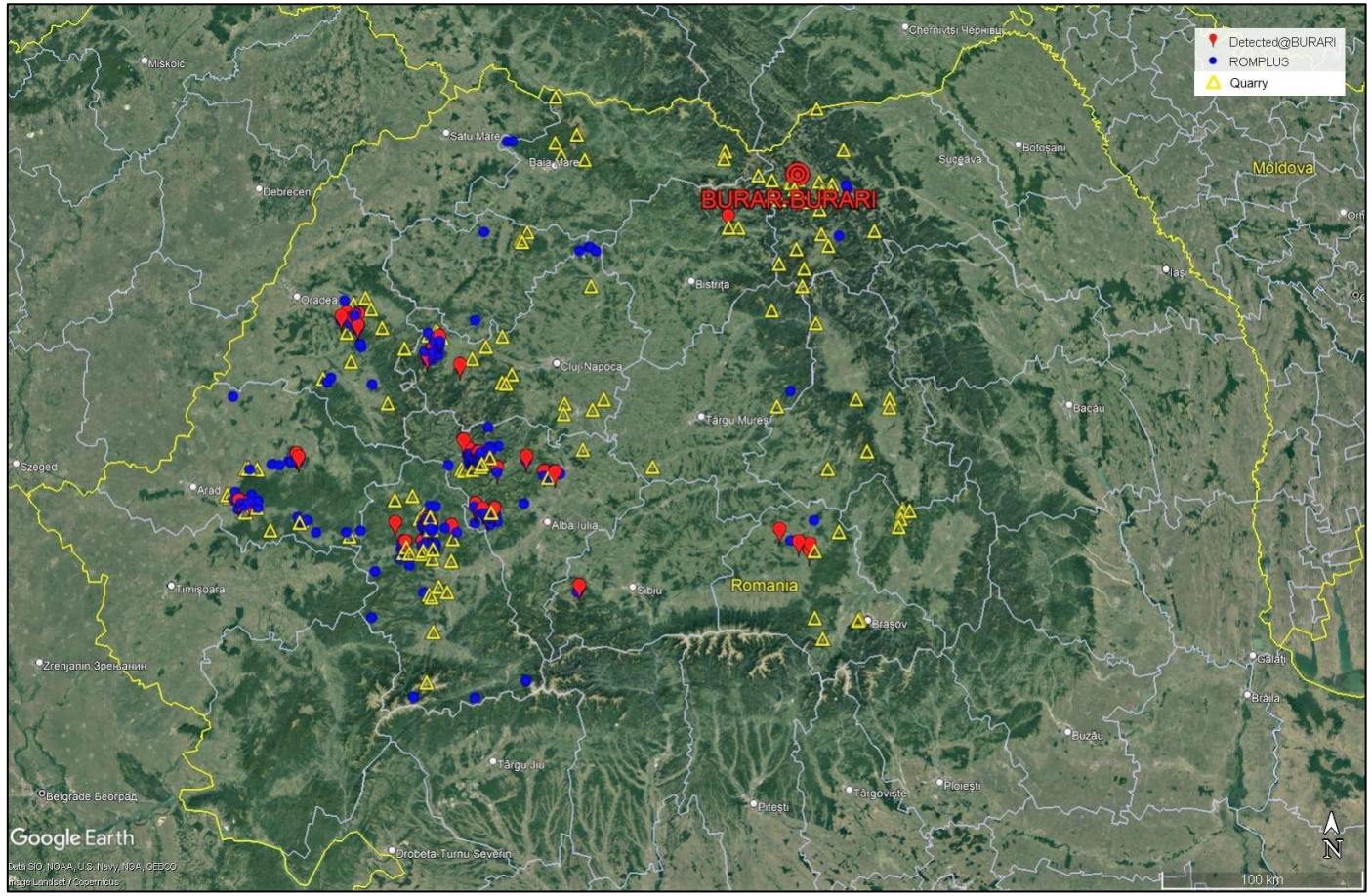
$$BAZ_i \sim BAZ_s$$

Identification of near-field quarries (2)

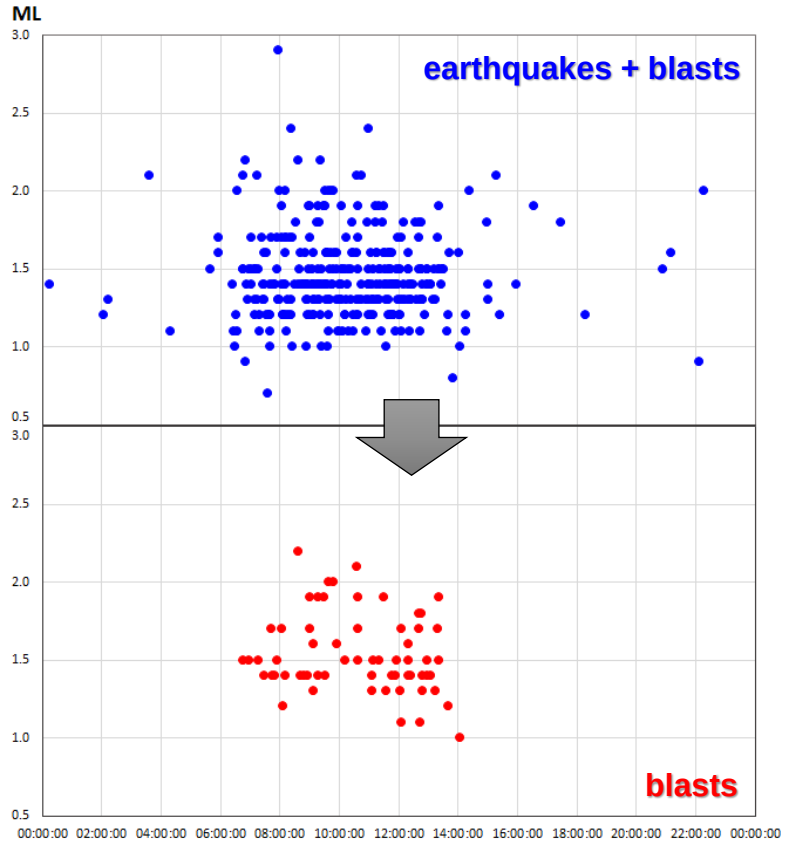


Identification of seismo-acoustic events (1)

- Updated Romanian seismic catalogue (ROMPLUS, *Oncescu et al., 1999**): local and near-regional sources, i.e., tectonic earthquakes *and* quarry blasts
- Discriminating between blasts and earthquakes by analysis of seismo-acoustic records



ROMPLUS catalogue, 2021 (selected region)

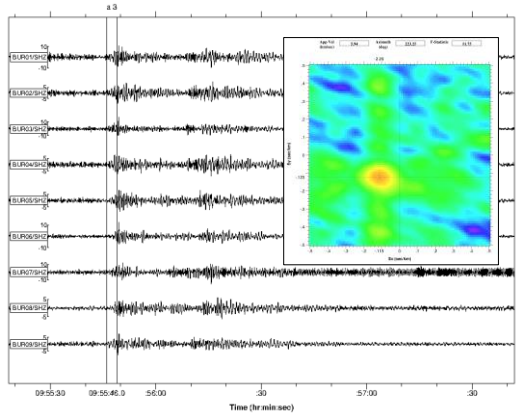


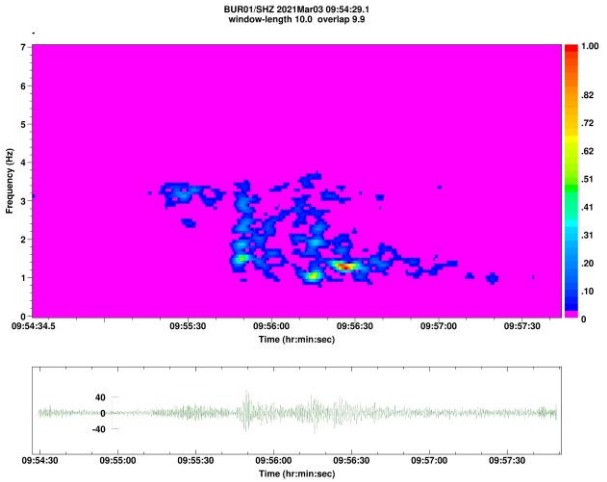
**Oncescu MC, Marza VI, Rizescu M, Popa M (1999). The Romanian Earthquake Catalogue between 984-1997, in Vrancea Earthquakes. Tectonics, Hazard and Risk Mitigation, F. Wenzel, D. Lungu (eds.) & O. Novak (co-ed), p. 43-47, Kluwer Academic Publishers, Dordrecht, Netherlands*

Identification of seismo-acoustic events (2)

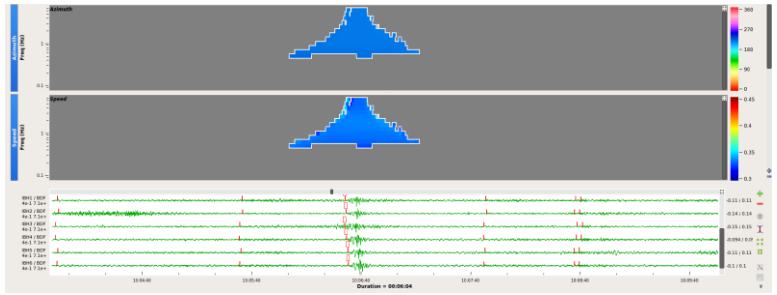
- Identifying quarry blasts: infrasonic signals detected by BURARI could be associated with seismic events listed in the ROMPLUS catalogue
- Distance range of interest up to 350 km: BURARI infrasonic array records both tropospheric and stratospheric phases
- Distances over 200 km: longer duration of the acoustic signals, travel time analysis indicates stratospheric path
- The ducting conditions towards the BURARI station are highlighted using InfraGA 2D ray tracer and NRL-G2S atmospheric models

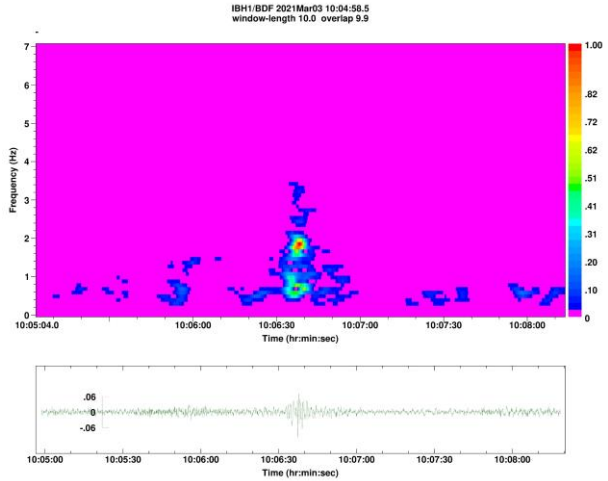
Seismic



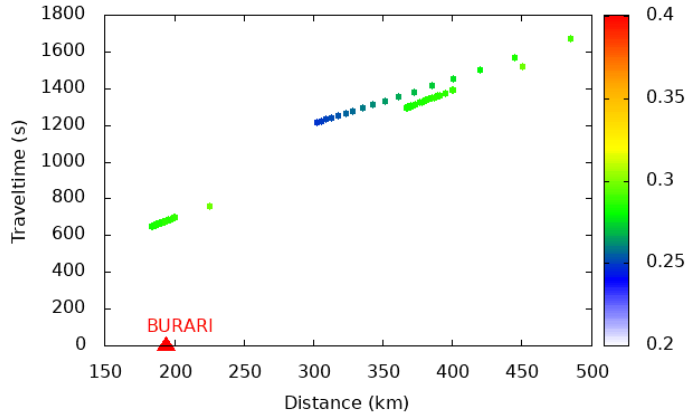


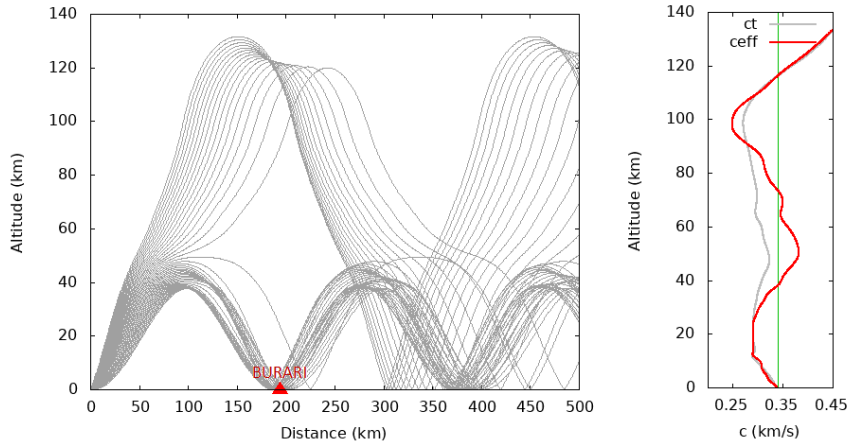
Infrasonic





Infrasound raytracing





Conclusions

- Impulsive and short-duration signals, generated by repeating sources confined in certain directions, are frequently detected during daytime both by the BURAR-BURARI seismo-acoustic array deployed in northern Romania
- As a number of active quarries are located in the local to near-regional distance ranges, we assumed that many of the seismo-acoustic signals, characterized with PMCC algorithm (for infrasound), and with f-k analysis (for seismic), are generated by the surface blasts conducted in these sites
- Two cases are addressed in this study:

  (1) The location of the local/near-field source is unknown: An empirical method for identification of near-field quarries, based on associating the seismic signal with the infrasonic arrival, is presented. The method is the most effective in the distance range of fastest infrasonic phases (direct or tropospheric), i.e., within 5 – 50 km of the infrasound array. Source location is based upon phase identification and characteristics (back azimuth, arrival time and apparent velocity) from both seismic and acoustic data.

  (2) The location of the local or near-regional source is listed in the updated Romanian seismic catalogue (ROMPLUS): Analysis of the seismo-acoustic records is applied to discriminate between anthropogenic events and earthquakes. In the distance range of interest (up to 350 km), the infrasonic array records tropospheric, stratospheric and thermospheric phases. Infrasonic signals detected by BURARI array were investigated in order to associate them with seismic events recorded in the ROMPLUS catalogue, and to identify quarry blasts. Based on the InfraGA 2D ray tracer and NRL-G2S atmospheric models, the ducting conditions towards the station are highlighted in order to explain the recordings.
- Joint analysis of the seismic and acoustic recordings has proven to be a useful tool for identifying and locating quarry blasting sources.

Acknowledgements

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