The use of IDC bulletins in assessing of Romanian infrasound stations performance to detect coherent infrasound sources at near-regional distance

Daniela Ghica, Dragoș Ene

National Institute for Earth Physics, Măgurele, Romania

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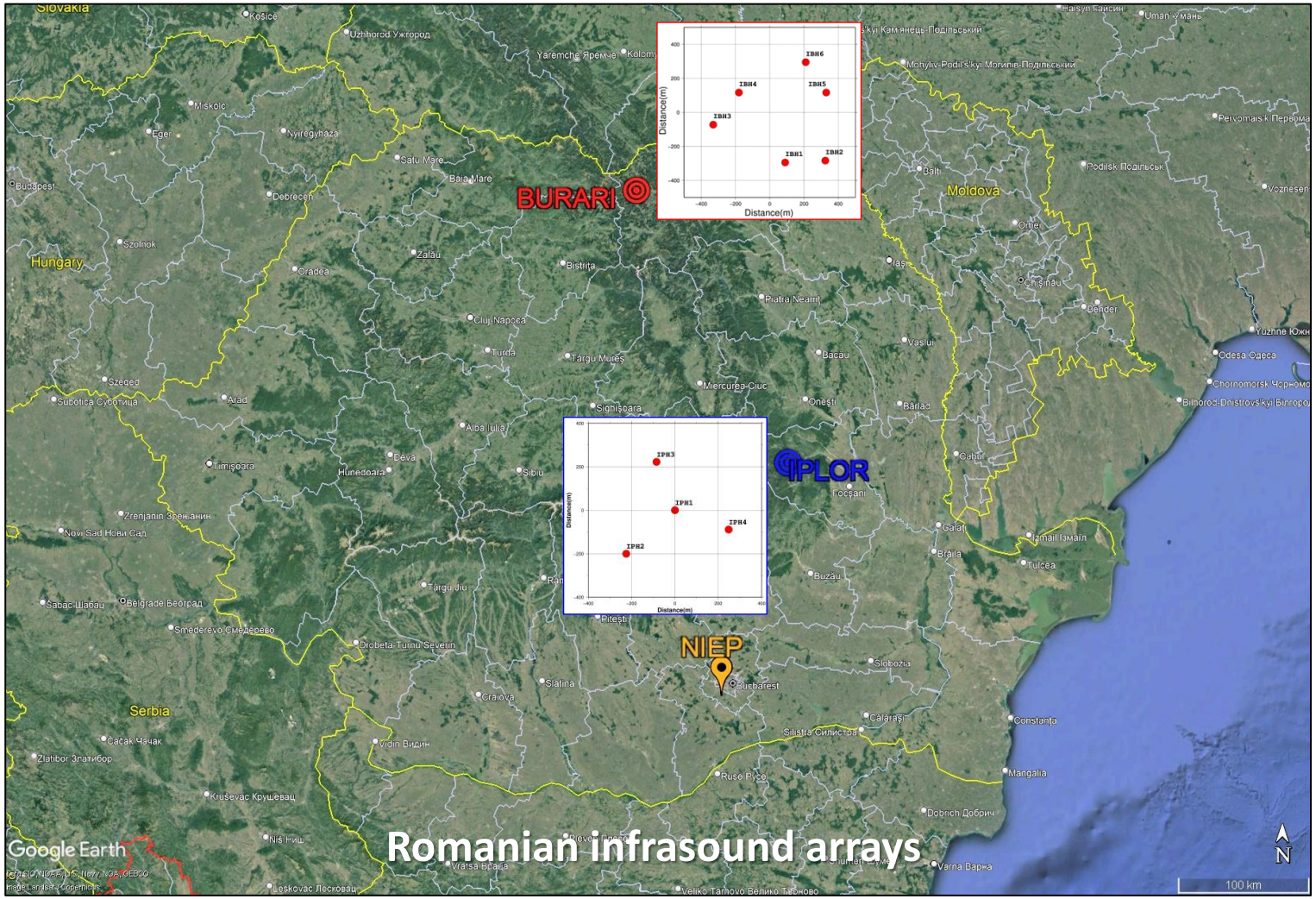
Overview



Station	Type	Location	No of elements	Sensors	Aperture (km)
BURARI	Infrasonic array	Benea, Suceava County	6	Hyperion IFS-5113	0.7
IPLOR	Infrasonic array	Ploştina, Vrancea County	4	Chaparral Physics Model 25	0.5

- Processing of Romanian infrasound data recorded in 2023 → Seasonal behaviour of the station detection performance in correlation with atmospheric dynamics
- Focusing on the high frequency signals (above 1 Hz) detected mainly from consistent sources related to the intense military activity caused by bombardment and shelling during the Ukraine war
- Sources with lower dominant frequencies, e.g., mountain waves, microbaroms, earthquakes, volcanoes and meteoroids are mostly suppressed by high filtering
- Showing several examples of infrasound detections originating from strong acoustic events produced by the intense explosive military activity throughout war in Ukraine, and observed with Romanian infrasonic arrays (BURARI and IPLOR) in 2023
- Ducting conditions towards stations were added by using the infraGA 2D (https://github.com/LANL-Seismoacoustics/infraGA) ray tracer through NRL-G2S atmospheric model (*Drob et al., 2003**)

*Drob, D.P., Picone, J.M., Garcés, M. (2003), Global morphology of infrasound propagation, J Geophys Res 108(D21):4680, DOI 10.1029/2002JD003307

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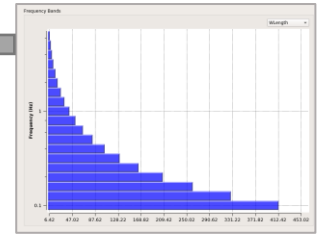
Infrasound data processing using NDC-in-a-Box

NDC-in-a-Box Virtual Machine

Run DTK-PMCC in automatic mode from command line (Python scripts)



- detection lists (one-day bulletins)
- results (one-day NetCDF4 files)

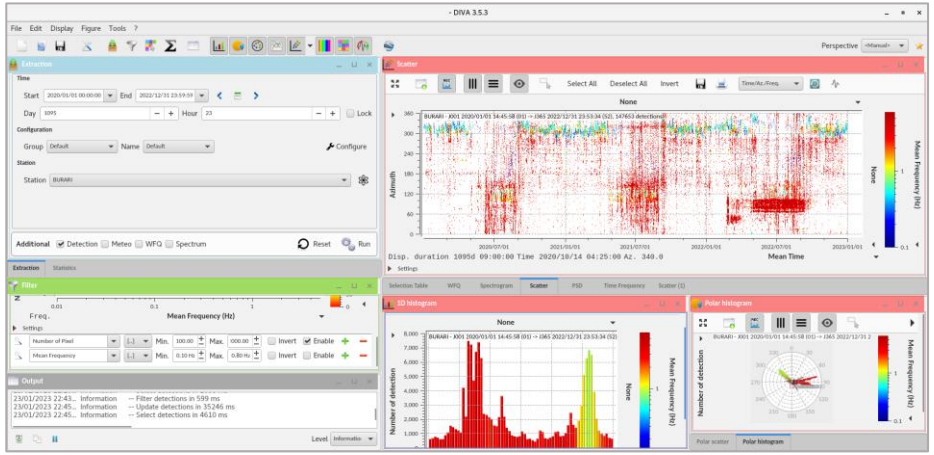
Results Analysis

DTK-GPMCC 6.11.5
visualize the detections in results file

- Interactively display/check results

DTK-DIVA 4.3.1
visualize the detections in bulletin files

- Identify and characterize sources of coherent noise/typical sources (station detection background): microbaroms, industrial noise, aircraft activity etc.
- Identify detections of interest, i.e., special infrasound source, occasionally detected at station: accidental explosions, exploding meteorites, volcanic eruptions etc.
- Recognize station detection patterns (diurnal, weekly, seasonal)



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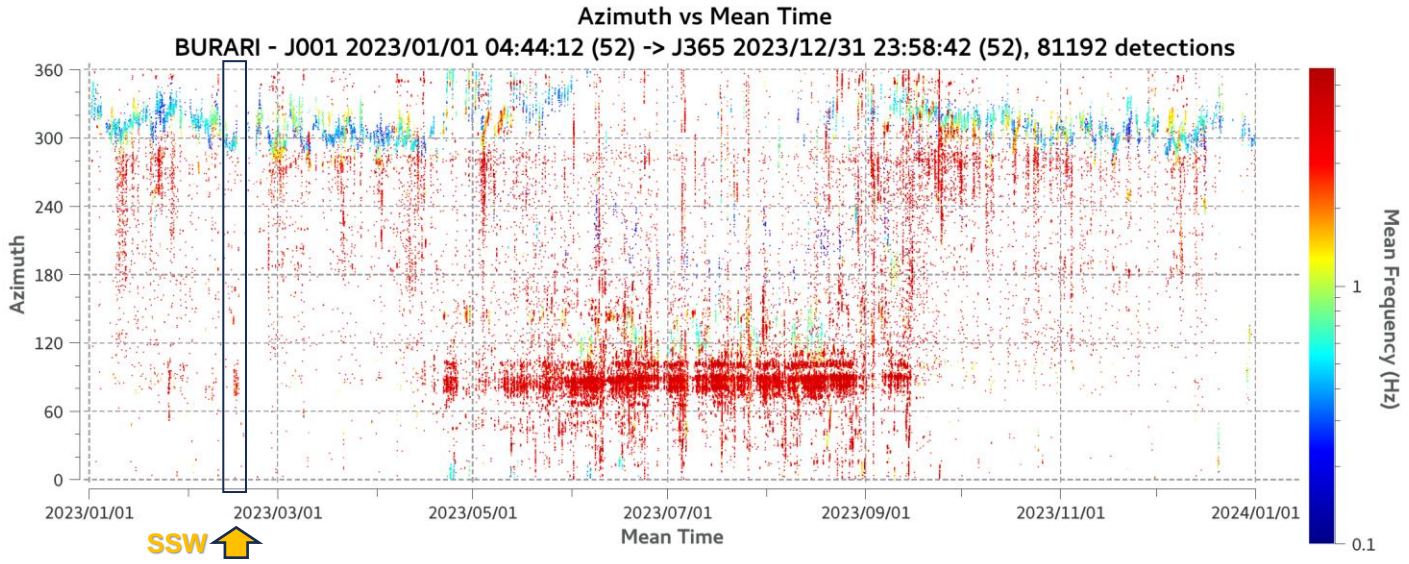
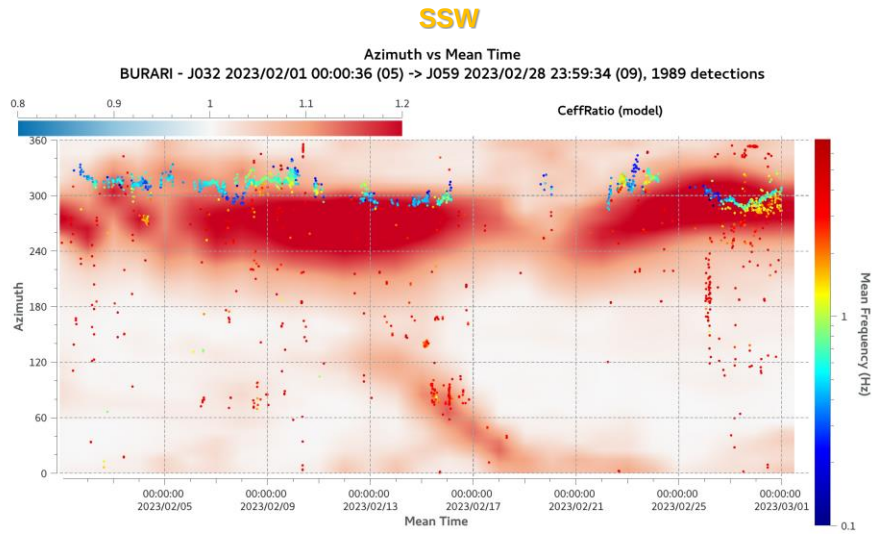
Station detection performance (2023)

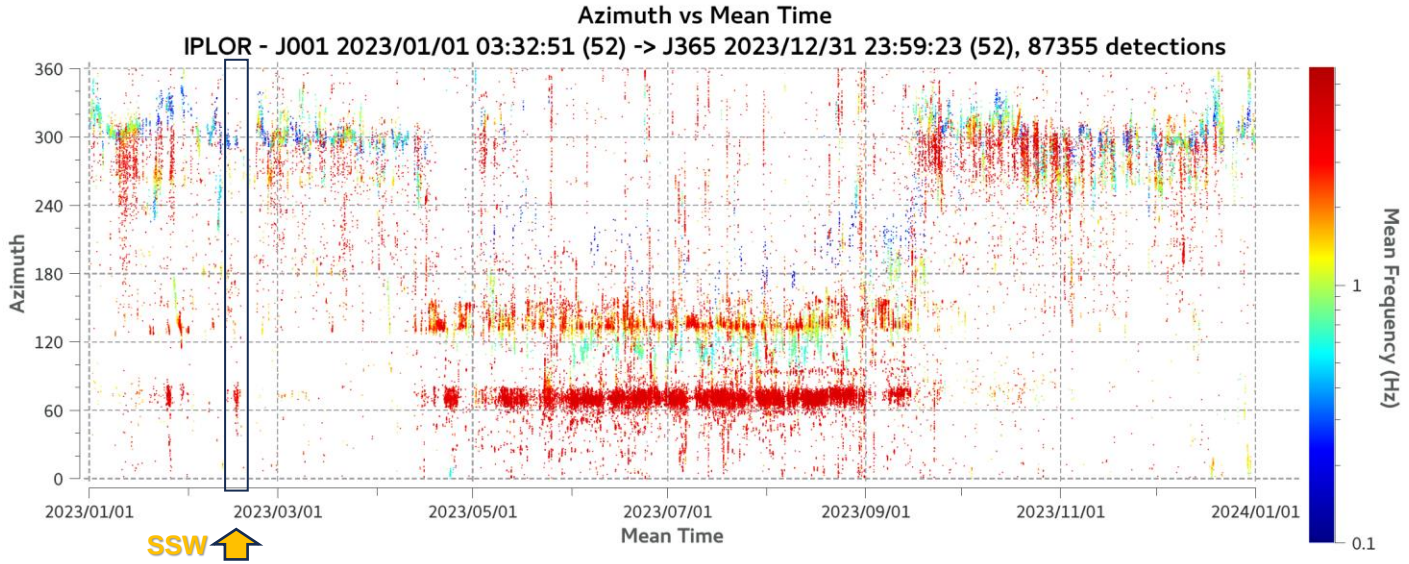
BURARI



SSW



IPLOR



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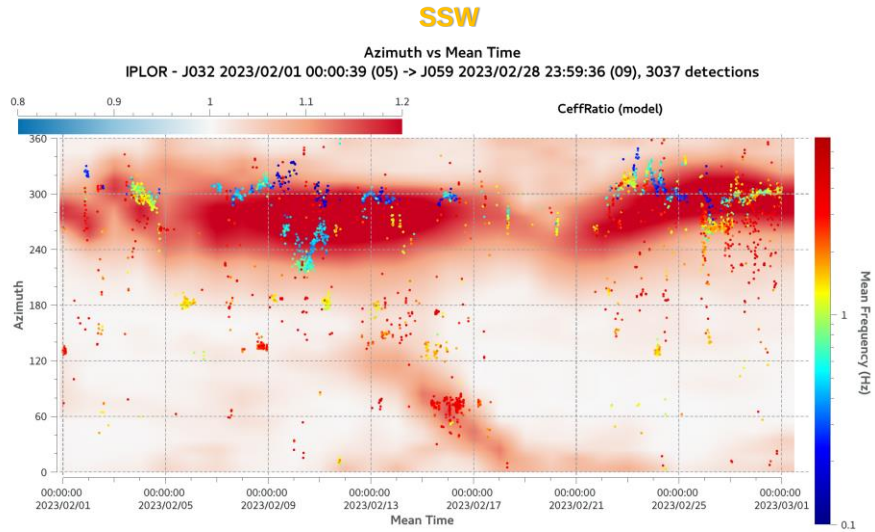

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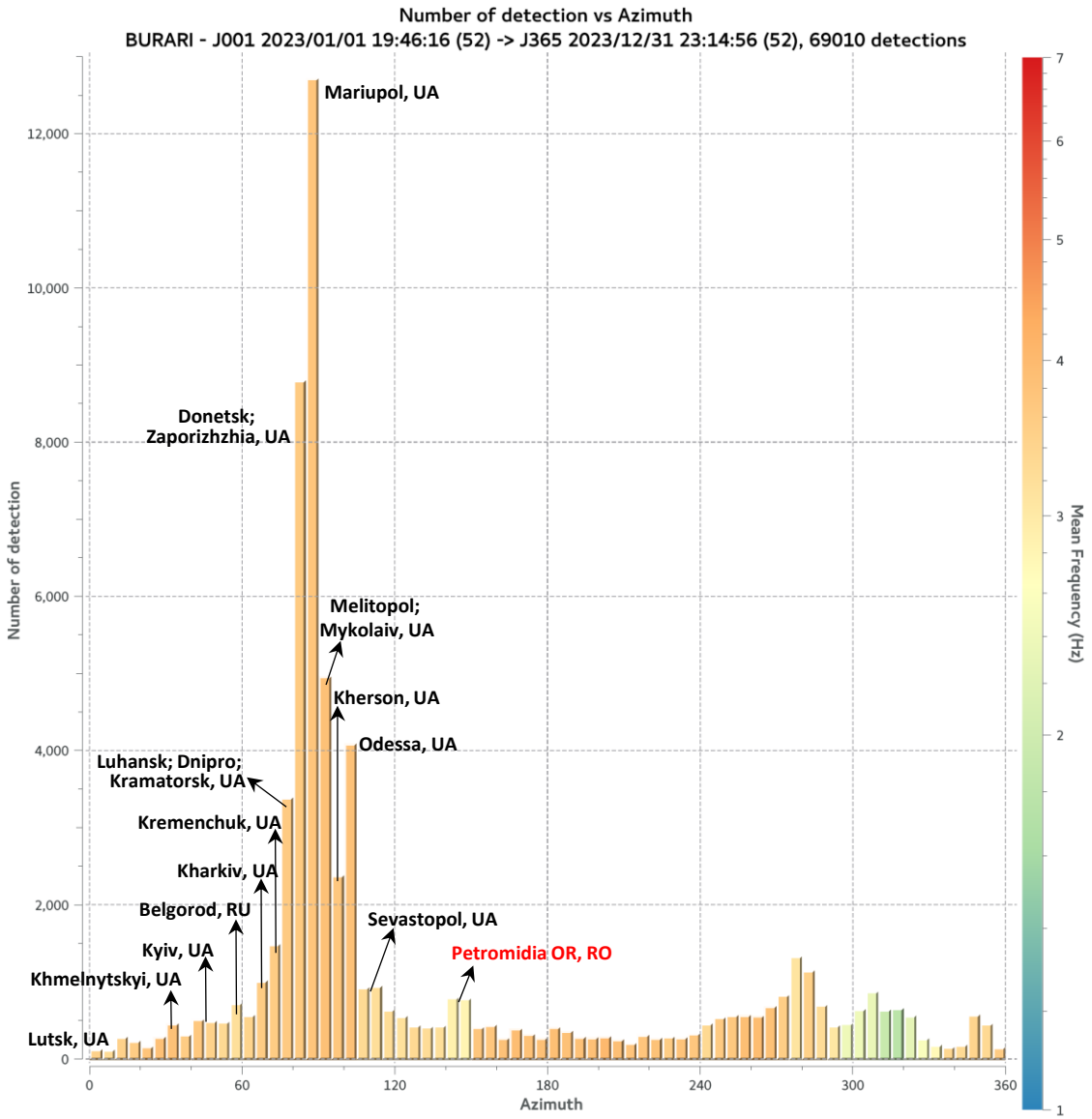
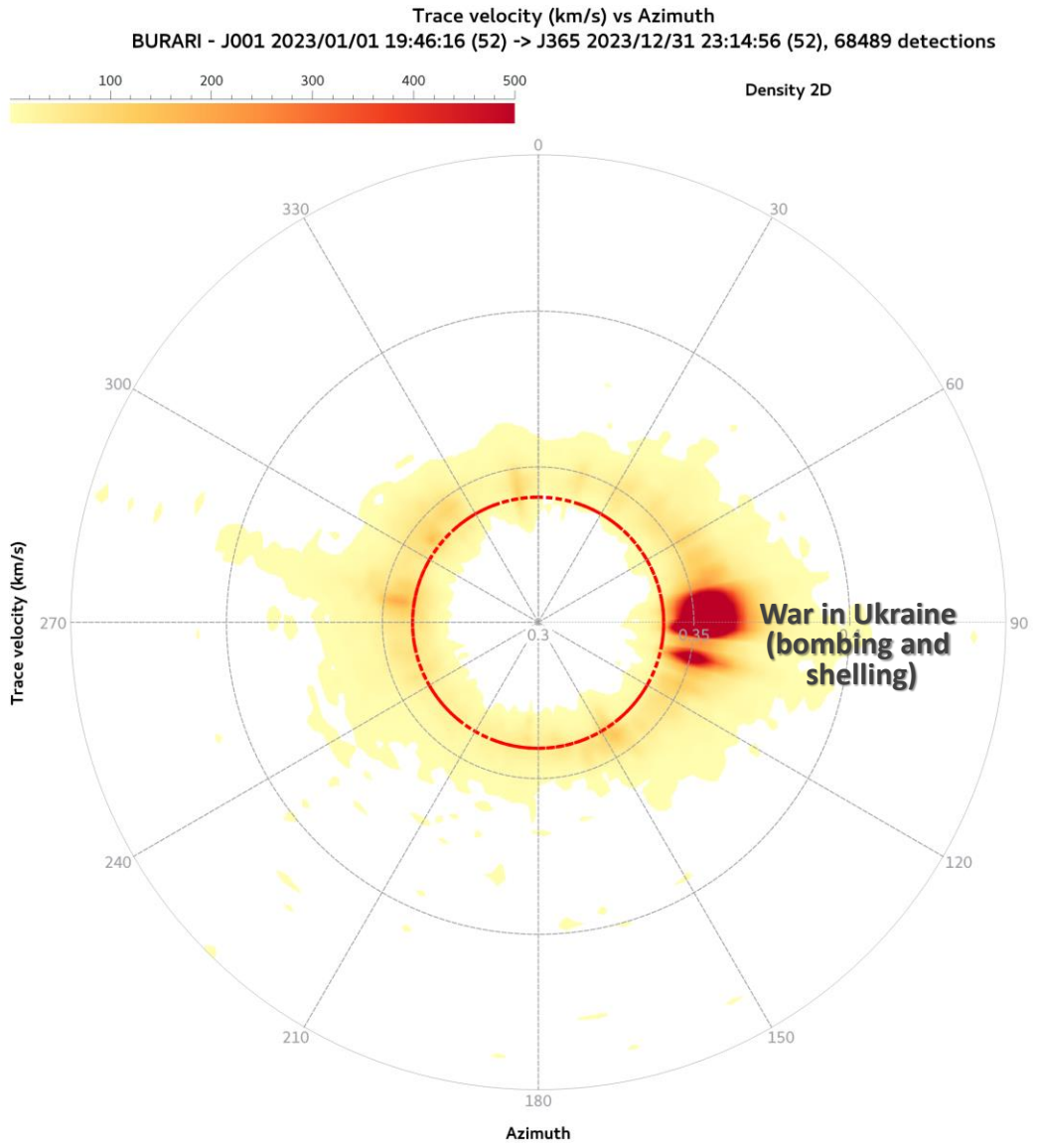
Repetitive coherent sources above 1 Hz at near-regional range (war in Ukraine)

BURARI





Repetitive coherent sources above 1 Hz at near-regional range (war in Ukraine)

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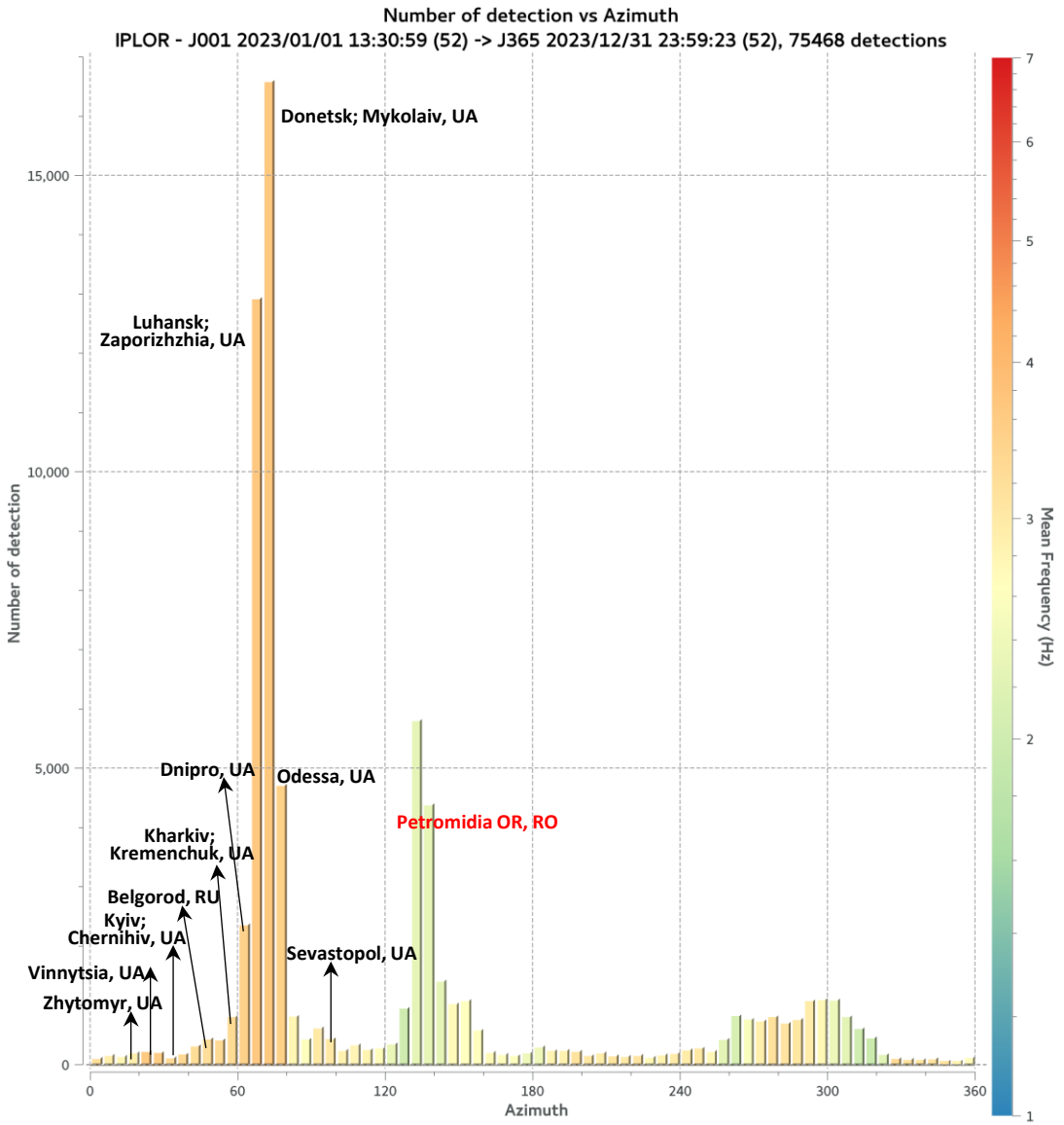

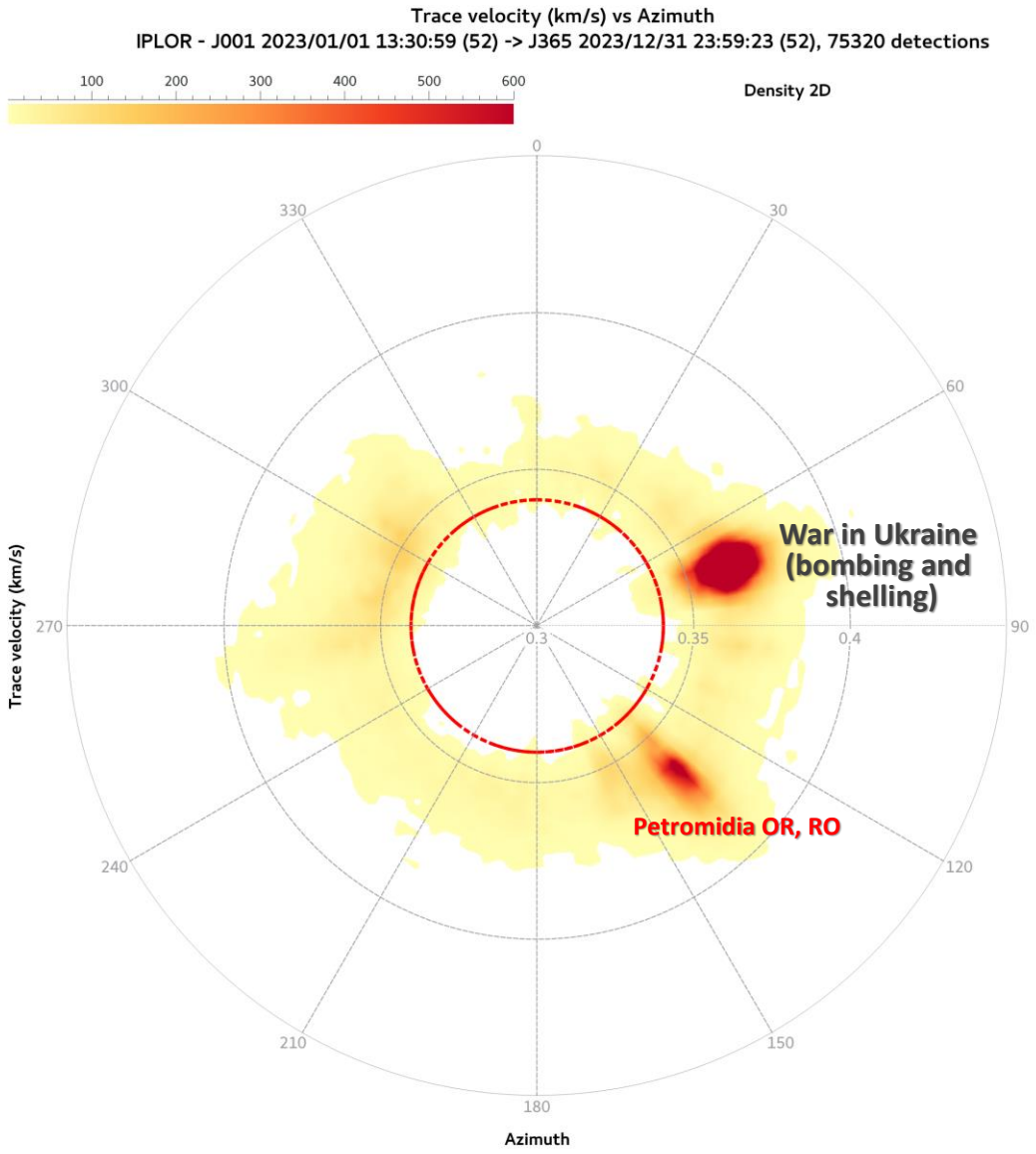

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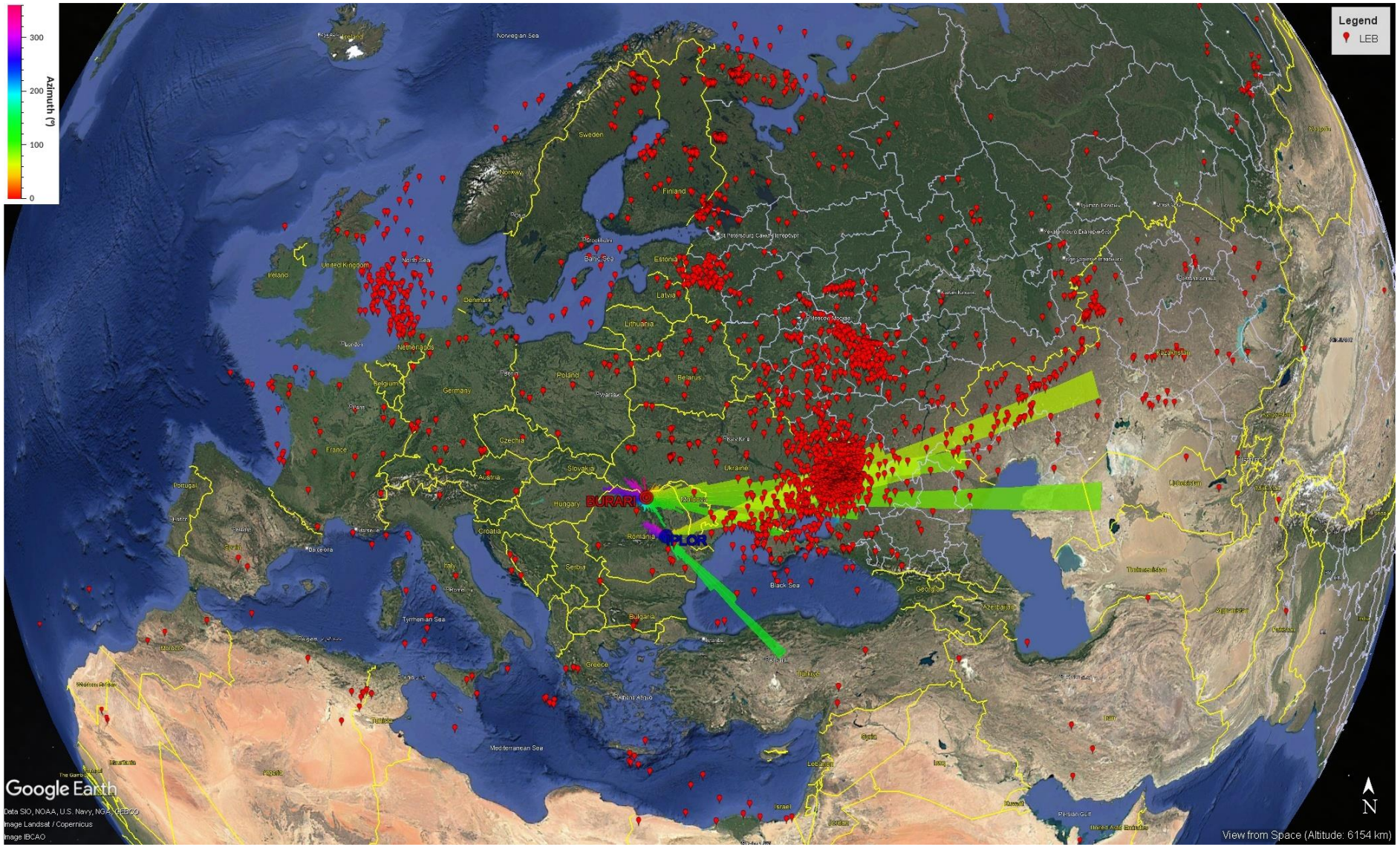
Association of infrasonic detections above 1 Hz with LEB locations

LEBs – total events

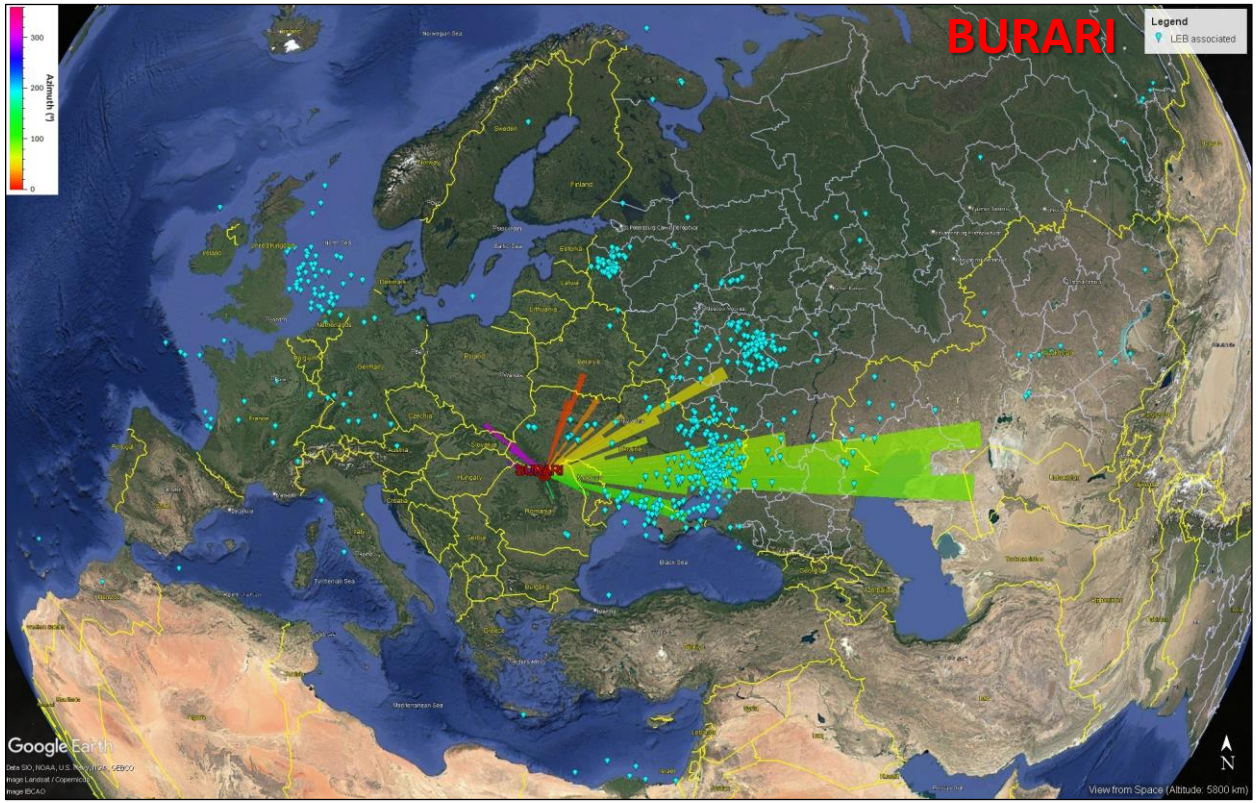


- 2204 LEBs retrieved for 01.01.2023 – 31.12.2023 time interval
- STA_LIST I26DE, I37NO, I31KZ, I48TN, I43RU
- Polar histogram plot of BURARI & IPLOR detections displayed with Google Earth for 2023
- LEBs retrieved for the analysis were added with red pins

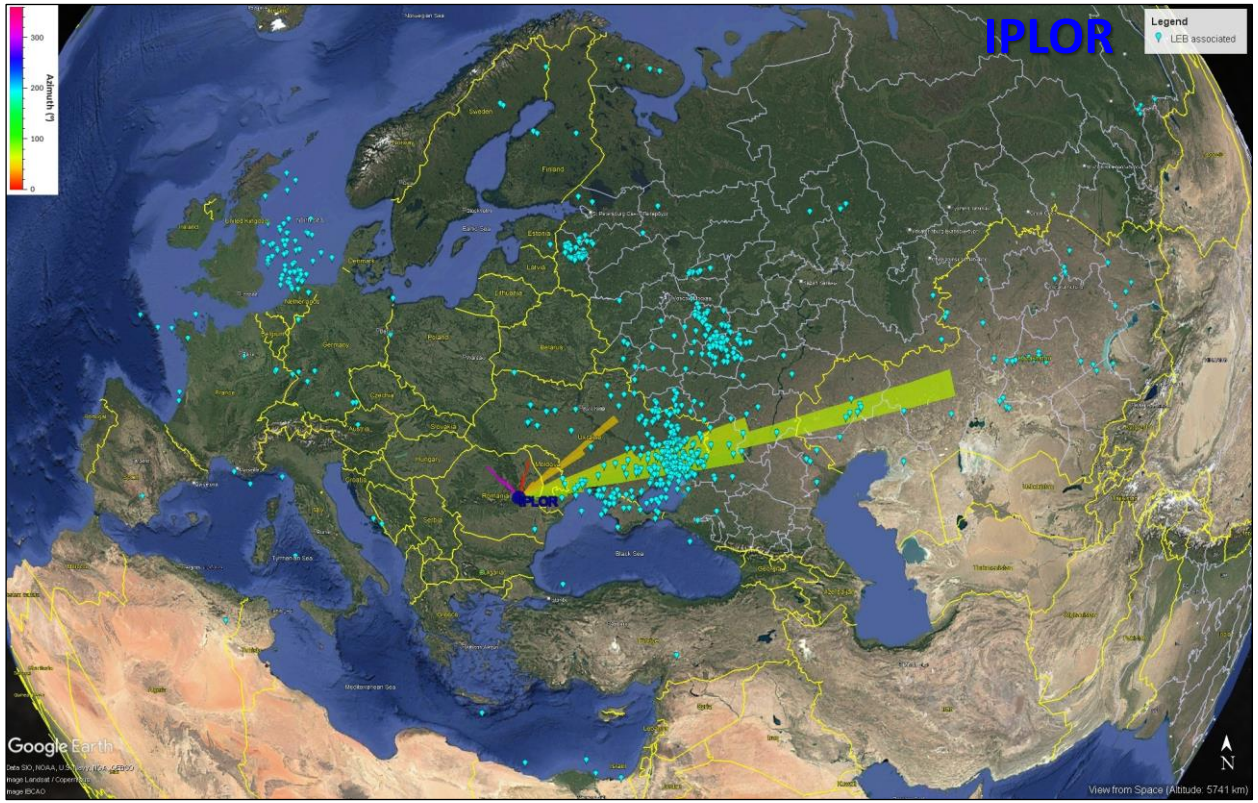
Association of infrasonic detections above 1 Hz with LEB locations

LEBs – associated events

- Allowed deviations between observed and expected values were considered as: ΔBAZ=±10 deg & Δt=±10 min
- Deviating effects of zonal cross winds along the propagation path through the atmosphere were not considered for observed BAZ
- Expected arrival time of infrasonic signal at arrays was estimated by adding the time of the sound wave to propagate to the arrays straight from the epicenter, with an average speed of 0.34 km/s, to the origin time of the LEB event (LEBs associated were added with cyan pins)



1967 infrasound detections associated with 559 LEBs
(approx. 25% of the LEBs total)



1985 infrasound detections associated with 600 LEBs
(approx. 27% of the LEBs total)

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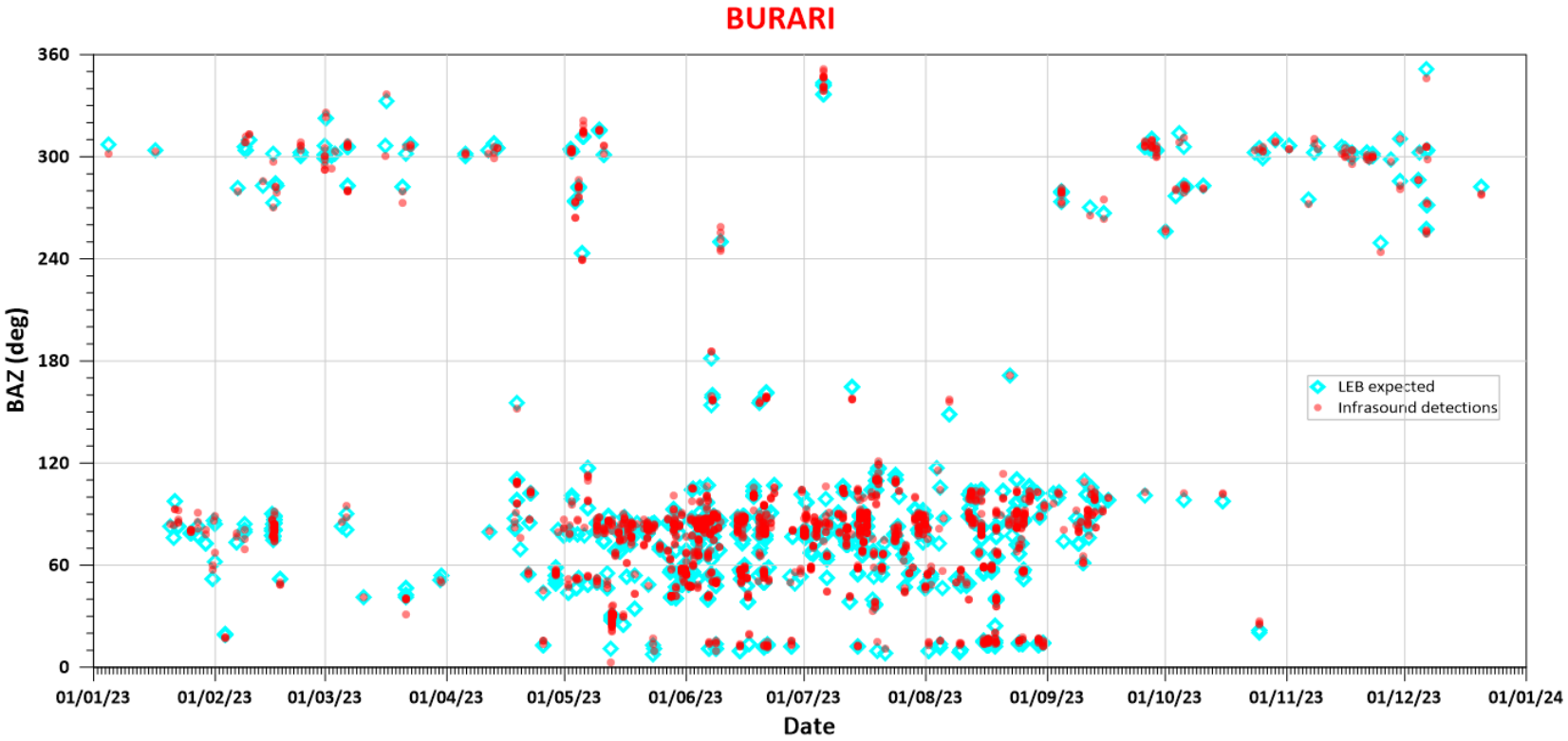
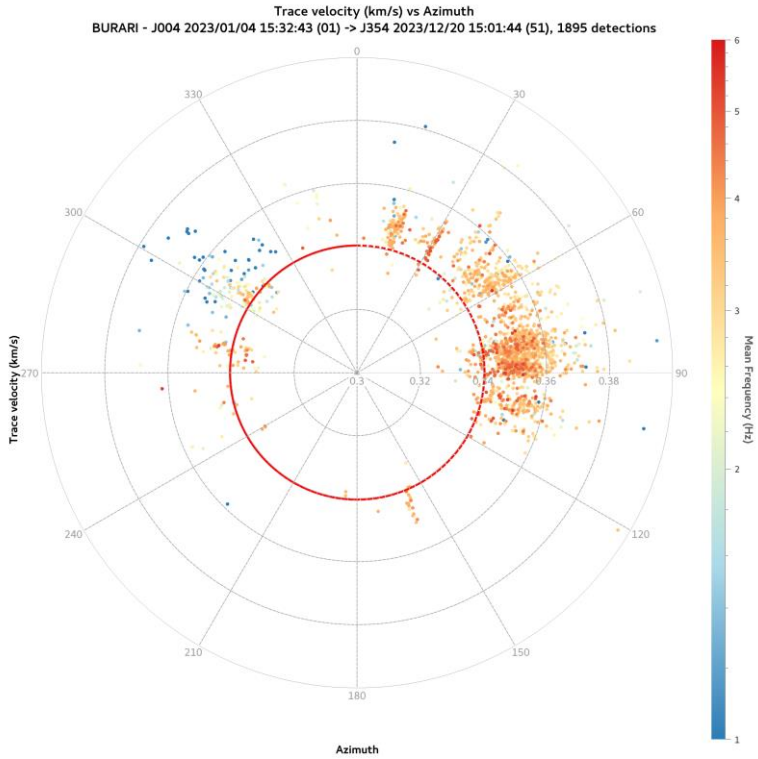
Infrasound detections associated with LEB locations

BURARI

- 1967 infrasound detections with frequency above 1 Hz were associated with 559 LEBs (approx. 25% of the LEBs total)

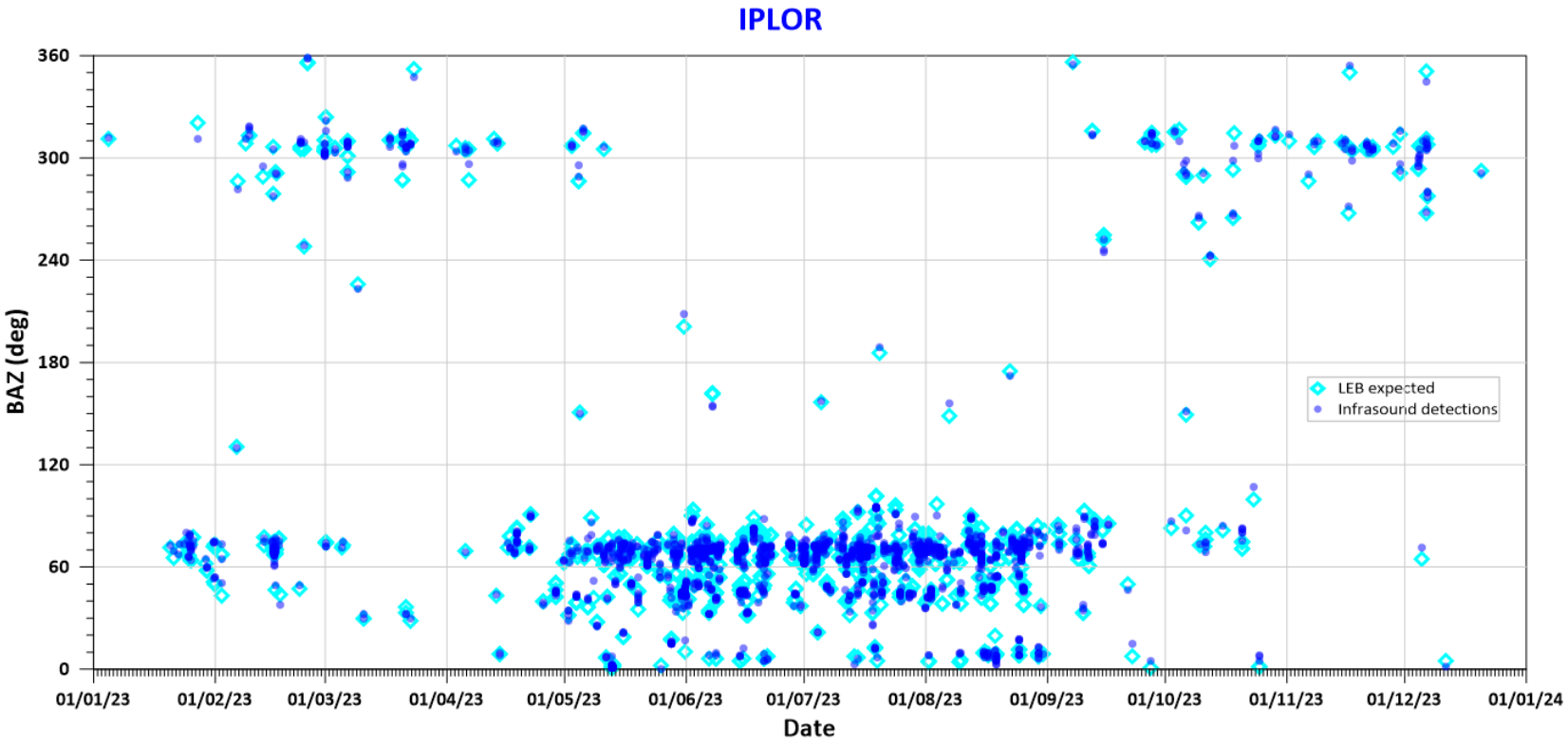


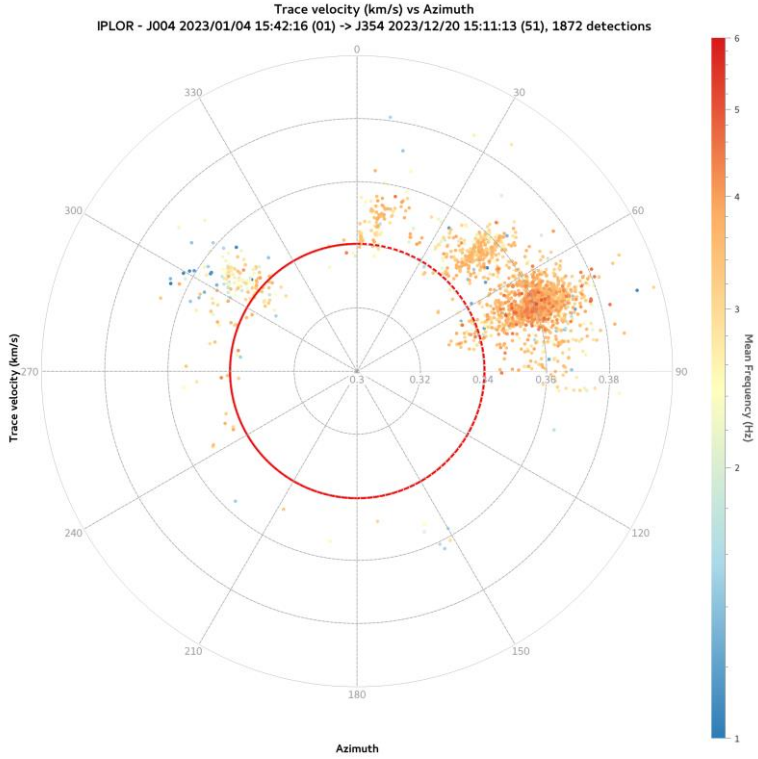


Infrasound detections associated with LEB locations

IPLOR

- 1985 infrasound detections with frequency above 1 Hz were associated with 600 LEBs (approx. 27% of the LEBs total)





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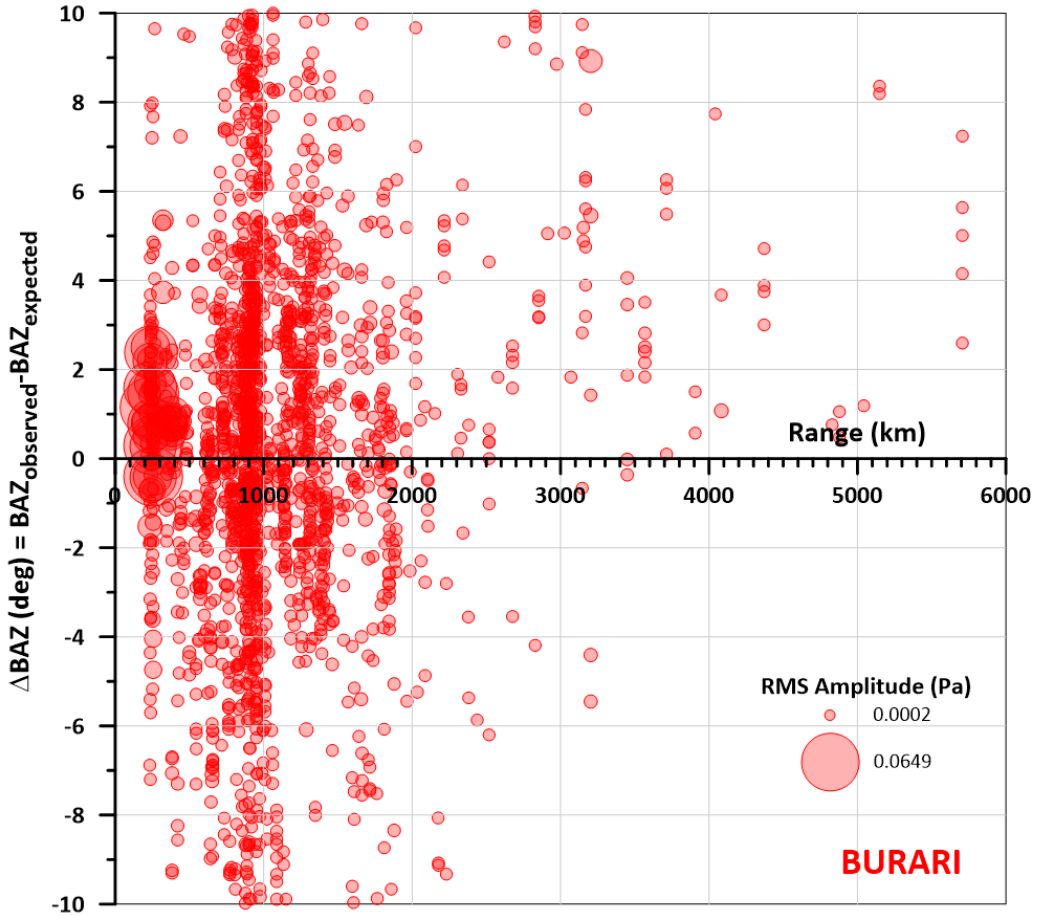
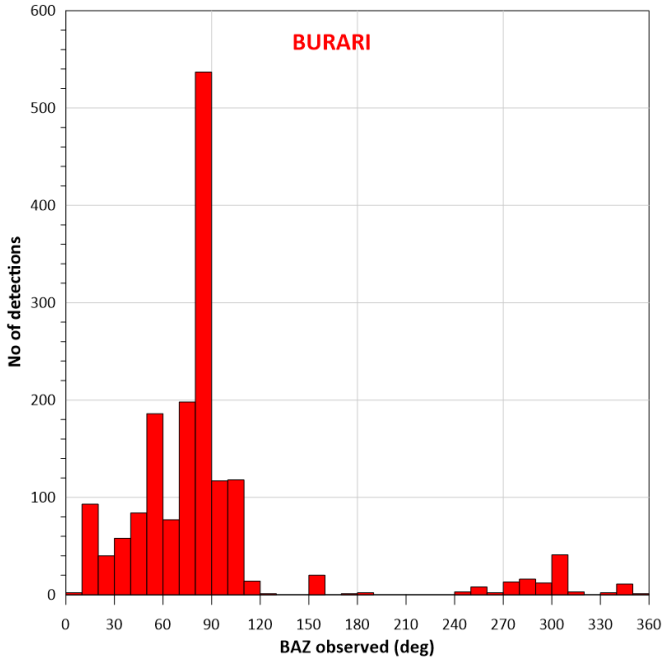
Infrasound detections associated with LEB locations

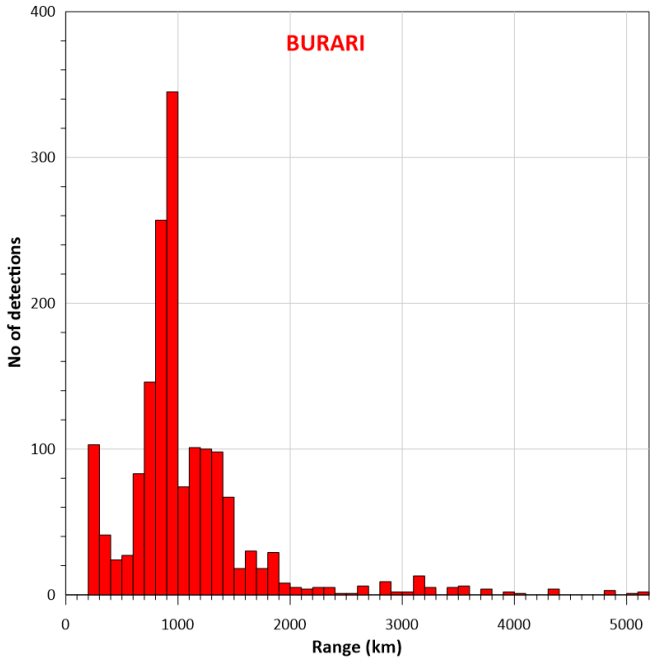
BURARI





For almost 90% of LEB associated events, the observed backazimuth values lie between 10 and 110 degrees

Almost 85% of LEB associated events are ranging between 230 and 1500 km from the array



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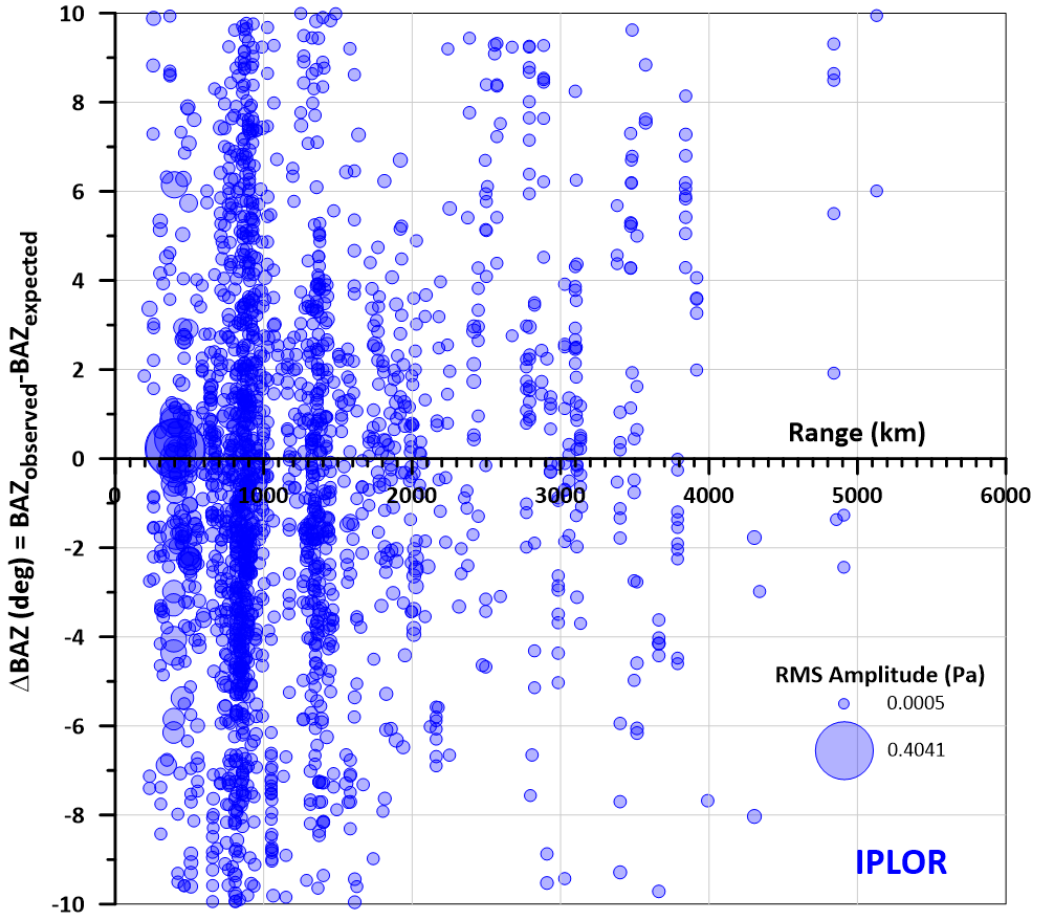
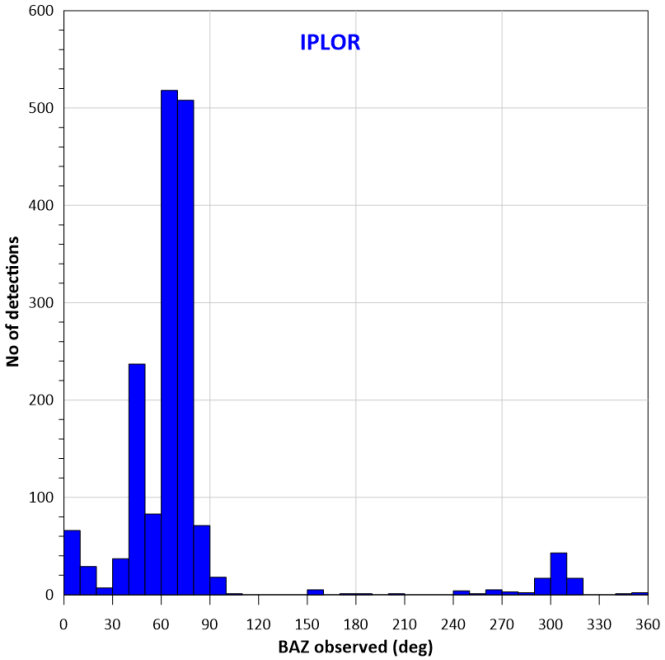
Infrasound detections associated with LEB locations

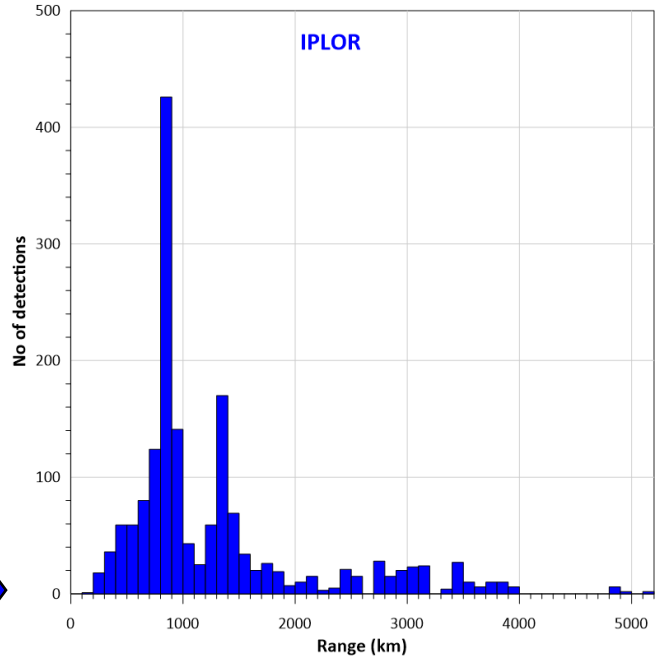
IPLOR





For almost 90% of LEB associated events, the observed backazimuth values lie between 0 and 110 degrees

Almost 80% of LEB associated events are ranging between 200 and 1500 km from the array



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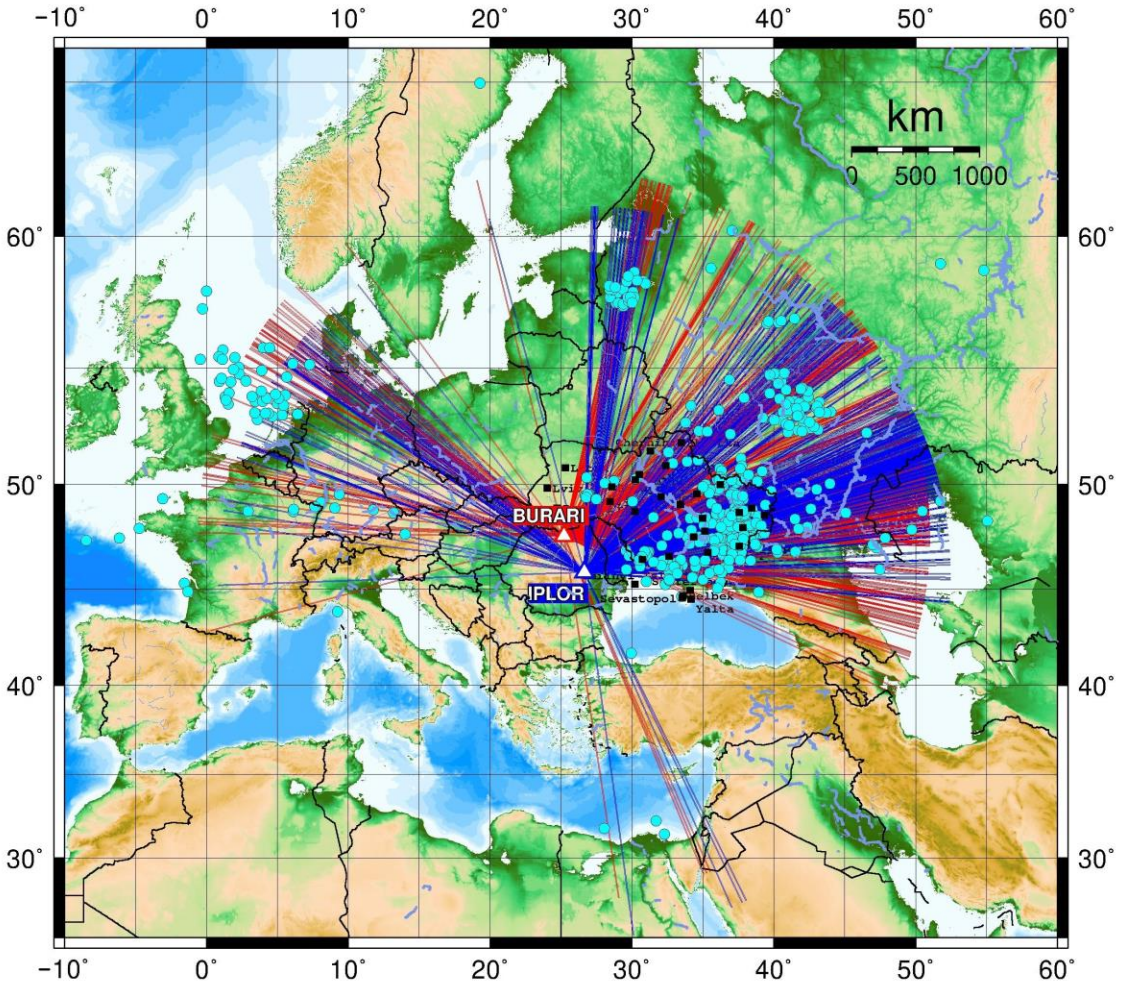
Association of infrasonic detections with LEB locations

LEB associated events - common detected by BURARI and IPLOR



433 LEB associated events were common detected by both arrays (approx. 20% of the LEBs total)

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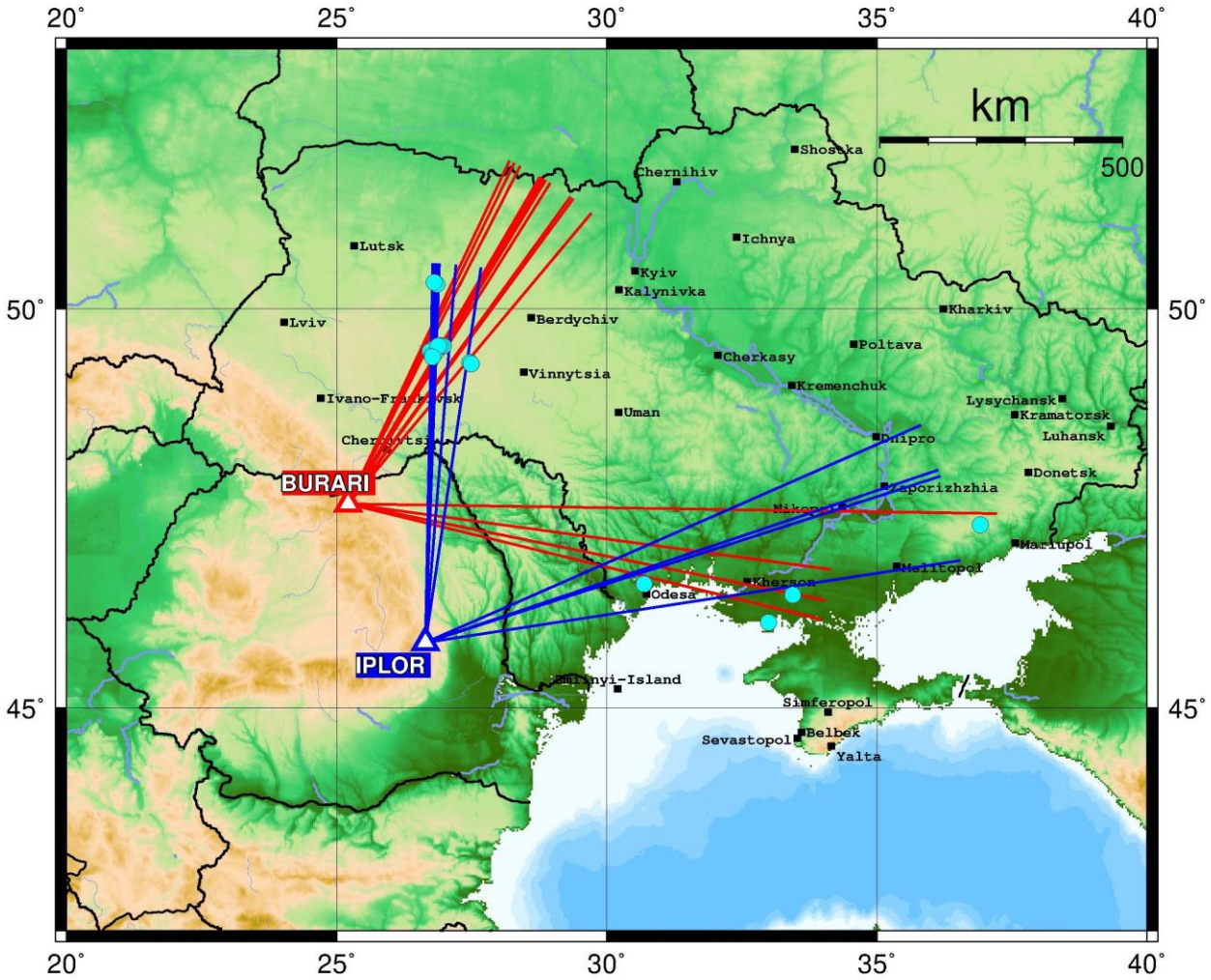
LEB events - common detected by BURARI and IPLOR (examples)



From the 433 LEB associated events common detected by both arrays, 7 examples of strong acoustic events produced by the intense explosive military activity throughout war in Ukraine are showed

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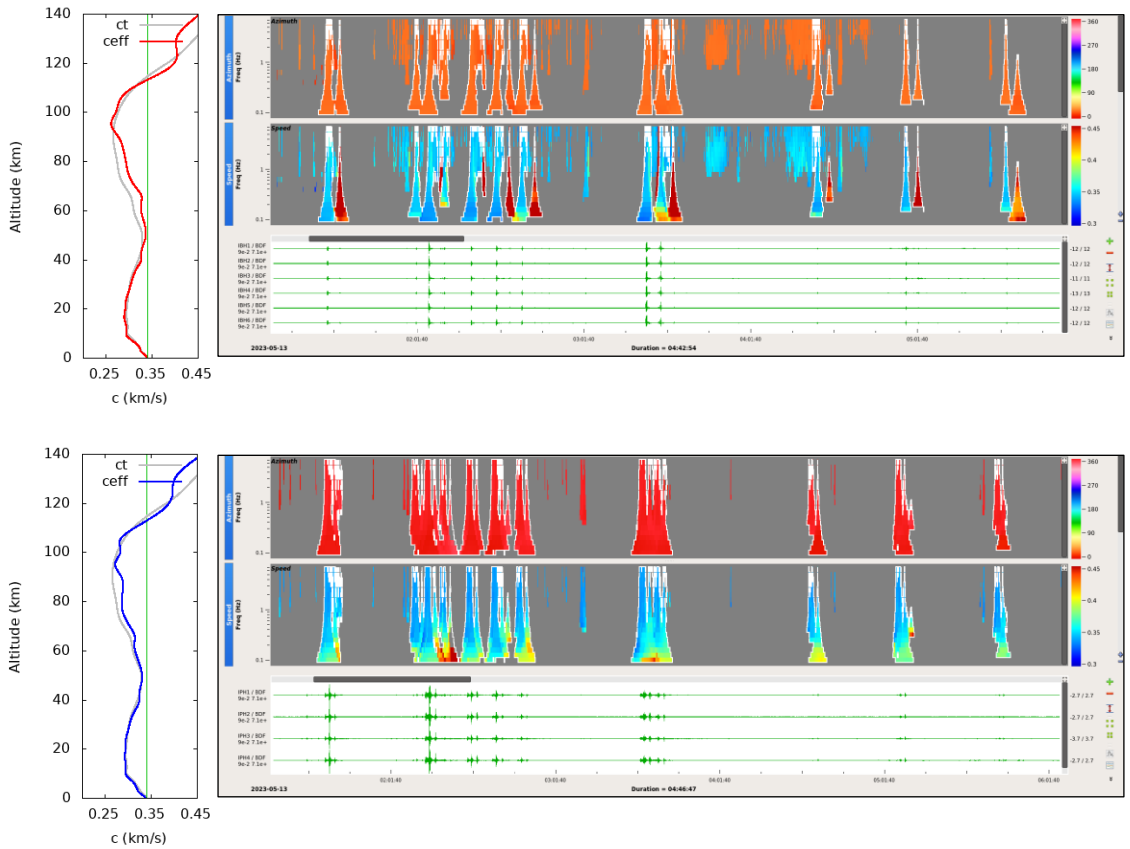
Association of infrasonic detections with LEB locations (examples)

13 May 2023, Shahed-131/136 drone strike against Ukraine (Khmelnytsky Oblast)

- Sharp-onset signals with high frequency content and large P-P amplitude (up to 18 Pa at BURARI and up to 7 Pa at IPLOR)
- Reported by IDC in 10 LEBs (using infrasound stations) and by NIEP in 9 REBs (using seismic stations)



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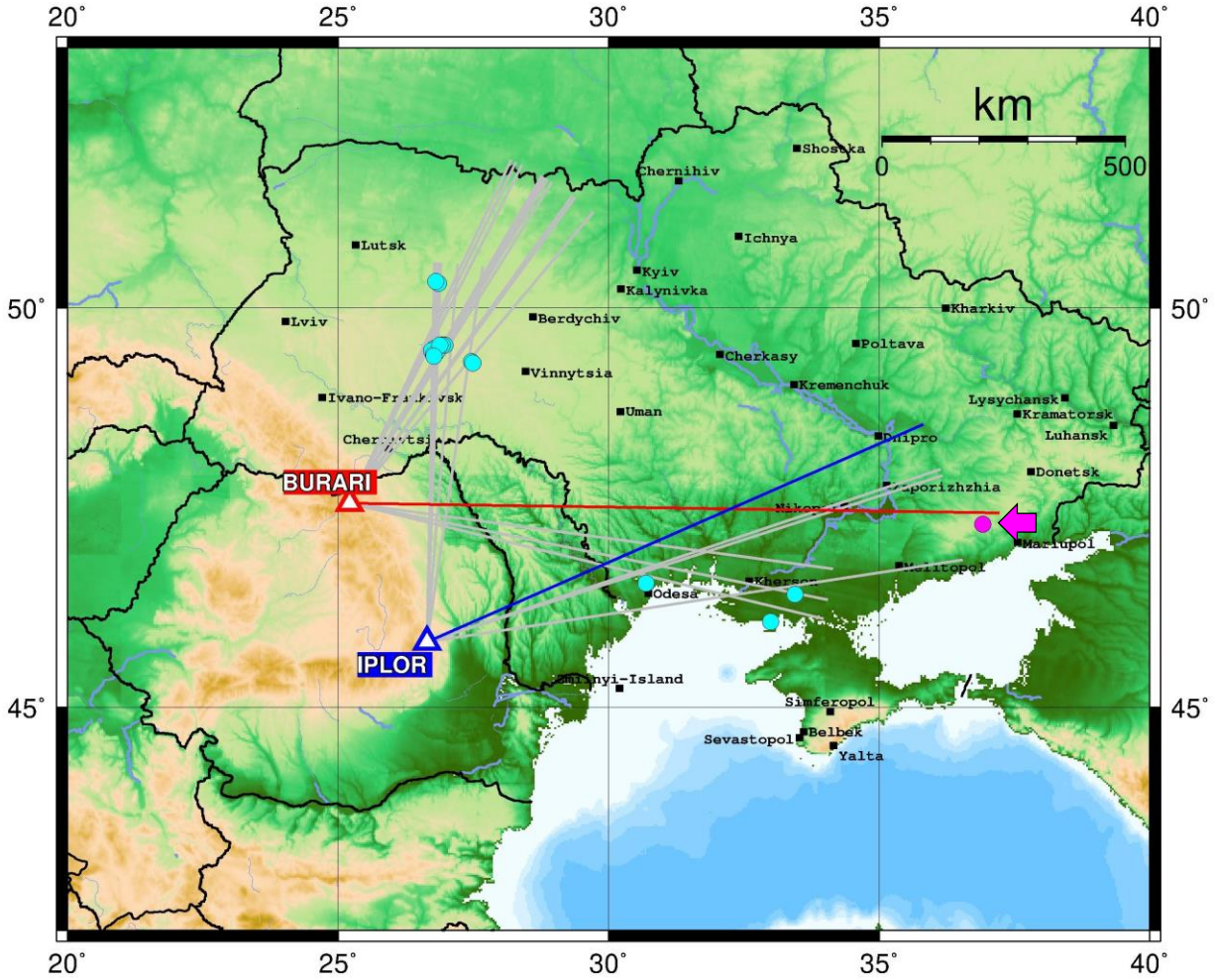
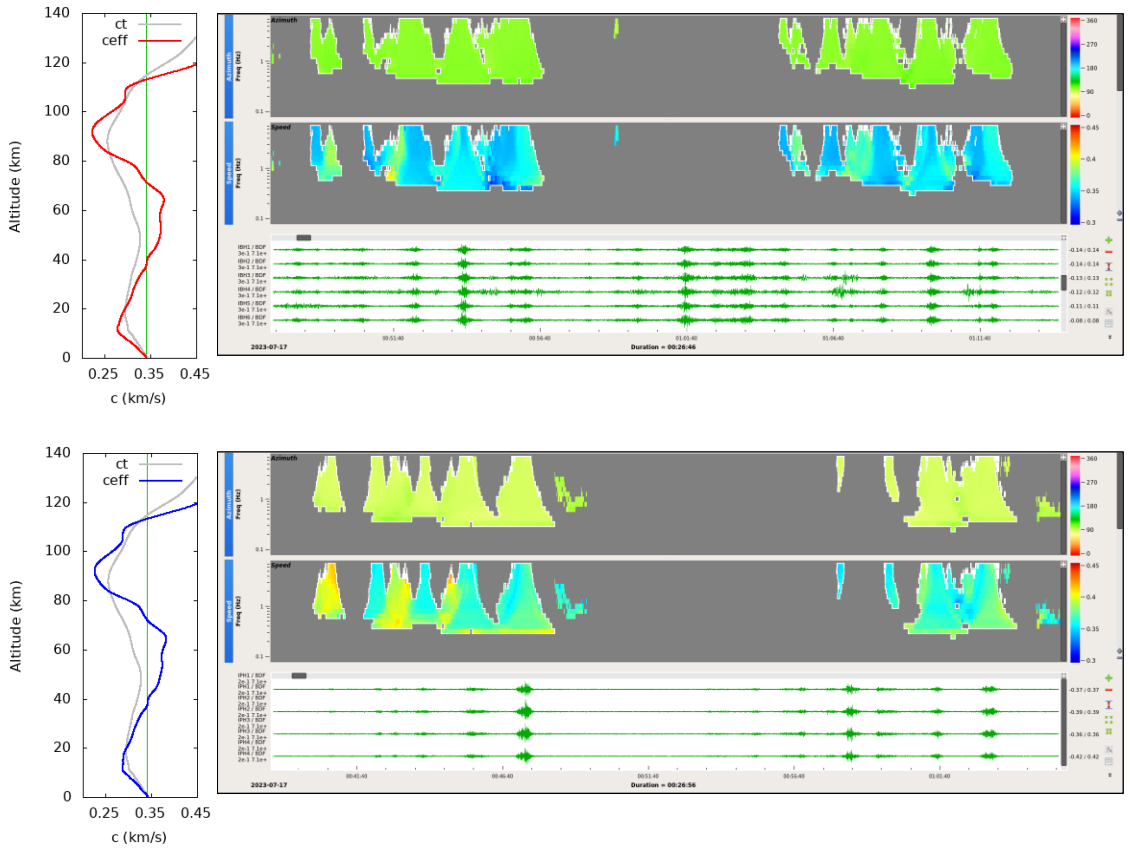
Association of infrasonic detections with LEB locations (examples)

17 July 2023, Crimean Kerch Bridge explosion

- P-P amplitude of infrasound signals: up to 0.2 Pa at BURARI and up to 0.4 Pa at IPLOR





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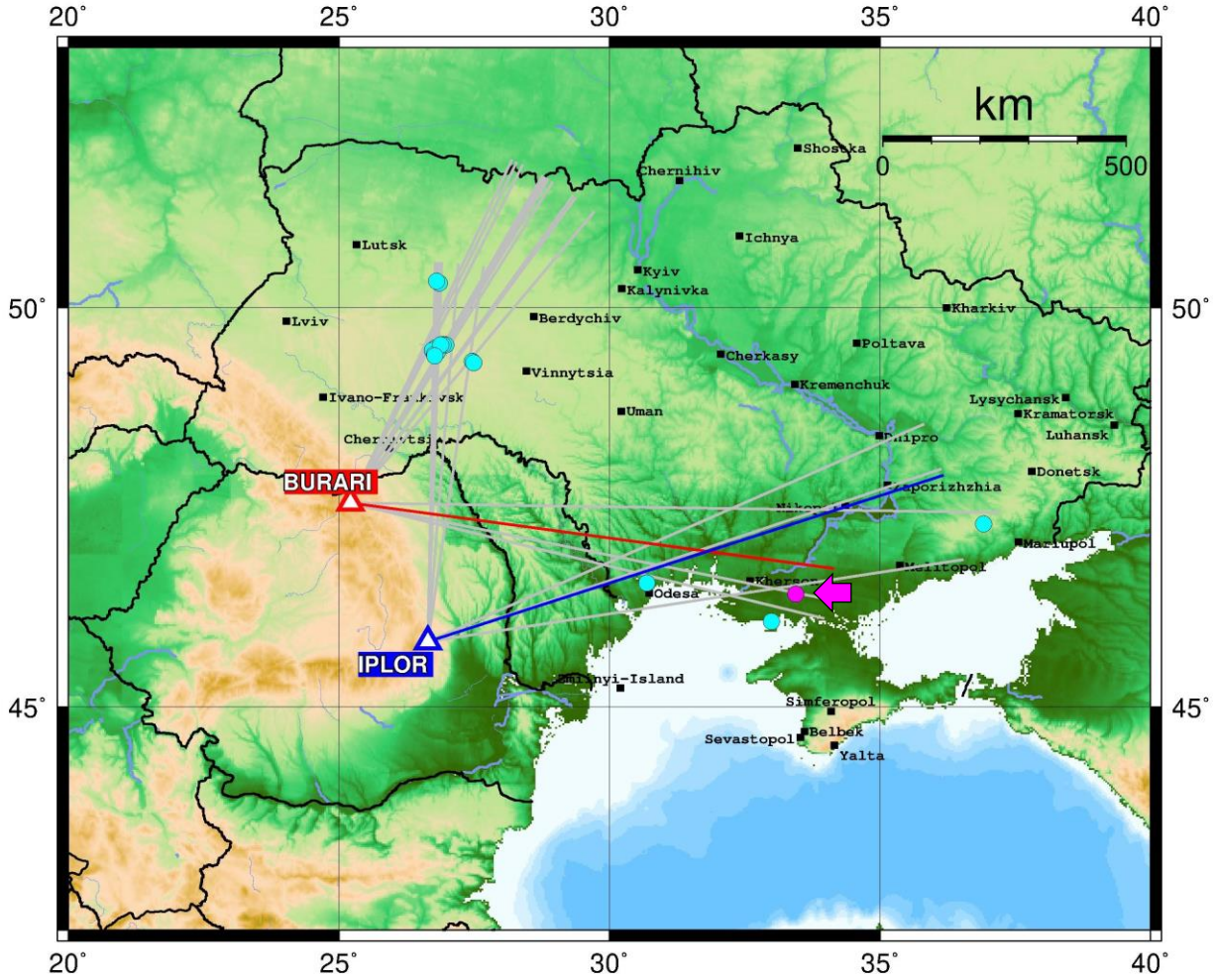
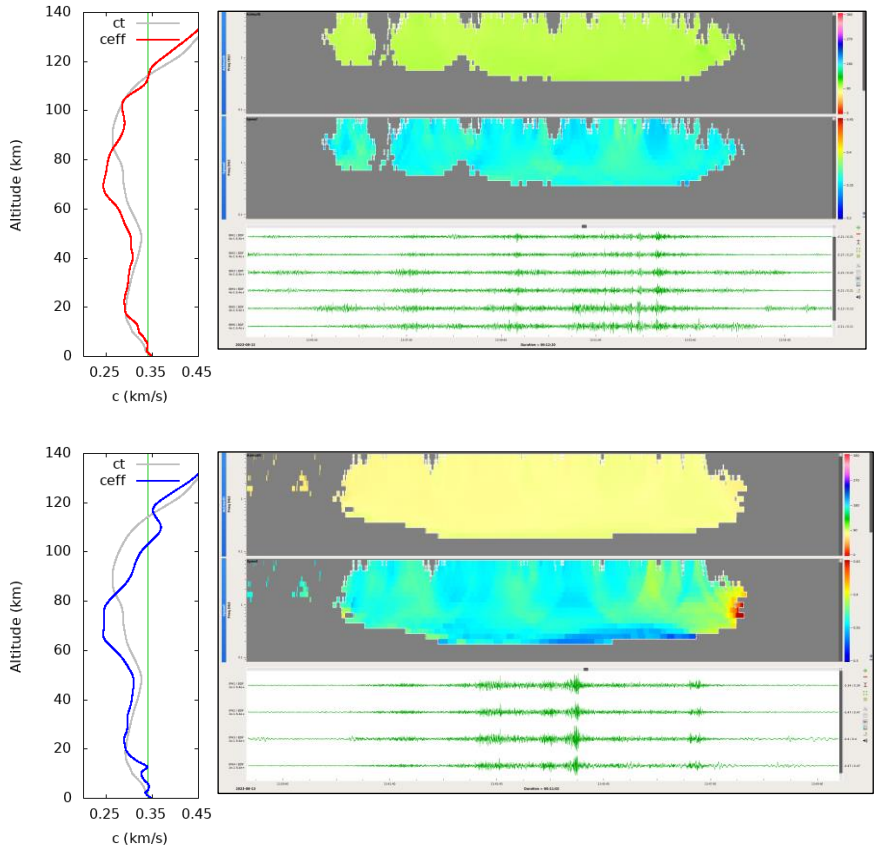
Association of infrasonic detections with LEB locations (examples)

13 August 2023, Russian shelling in Kherson Oblast

- P-P amplitude of infrasound signals: up to 0.2 Pa at BURARI and up to 0.5 Pa at IPLOR





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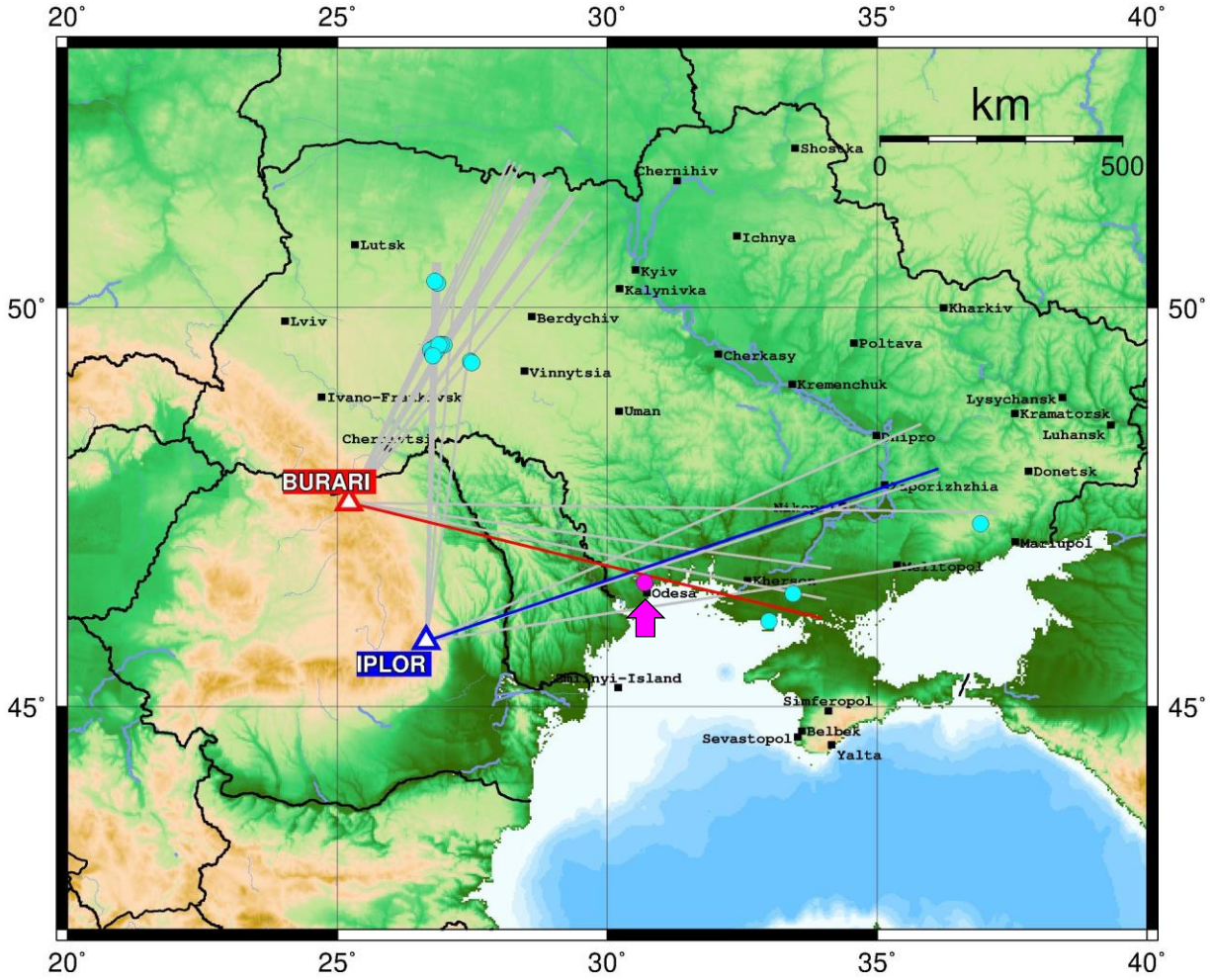
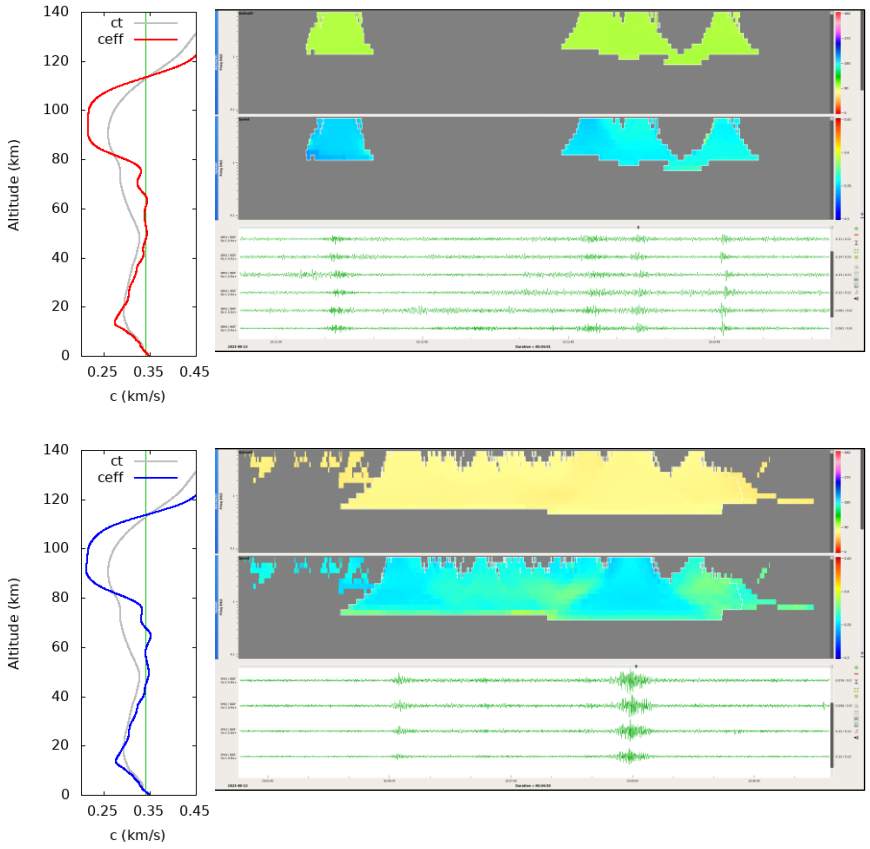
Association of infrasonic detections with LEB locations (examples)

13 August 2023, Russian drone and missile attacks on Odessa

- P-P amplitude of infrasound signals: up to 0.1 Pa at BURARI and up to 0.1 Pa at IPLOR





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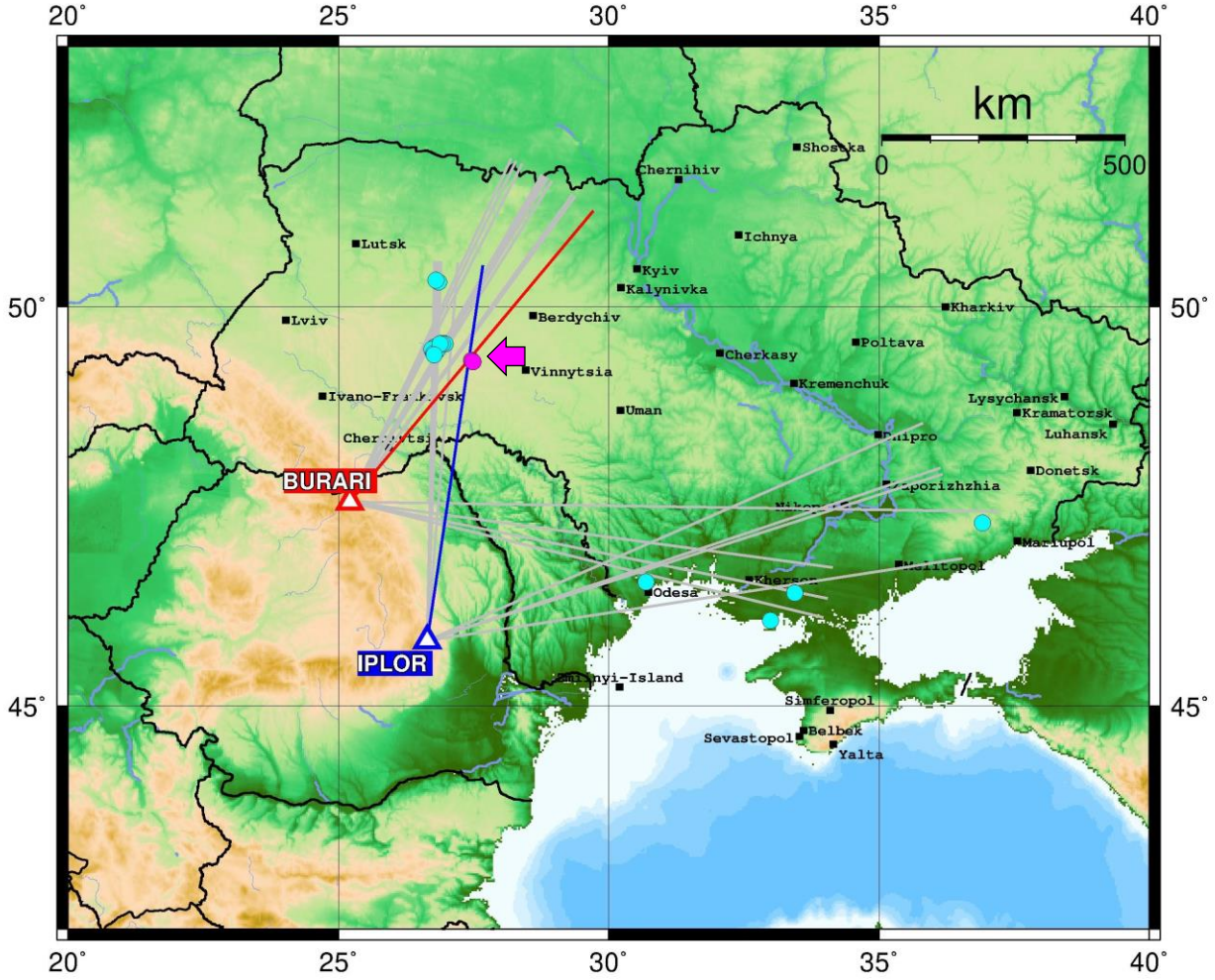
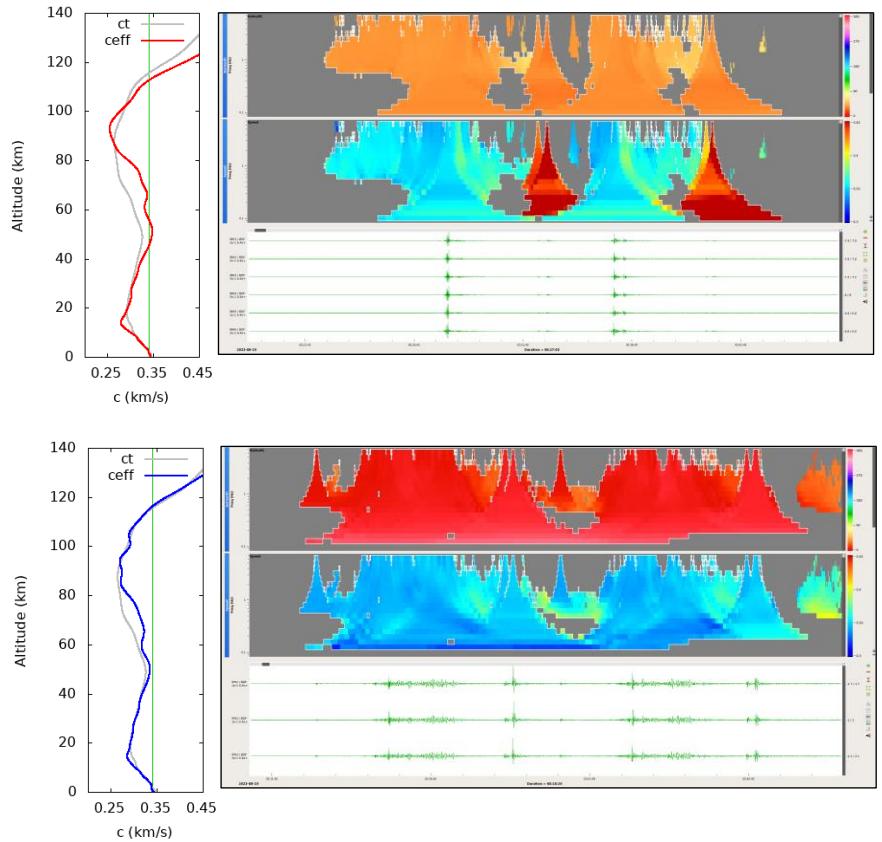
Association of infrasonic detections with LEB locations (examples)

19 August 2023, Russian drones attack on Khmelnytskyi ammunition and explosives storage

- P-P amplitude of infrasound signals: up to 13.9 Pa at BURARI and up to 2.2 Pa at IPLOR
- Two LEBs associated





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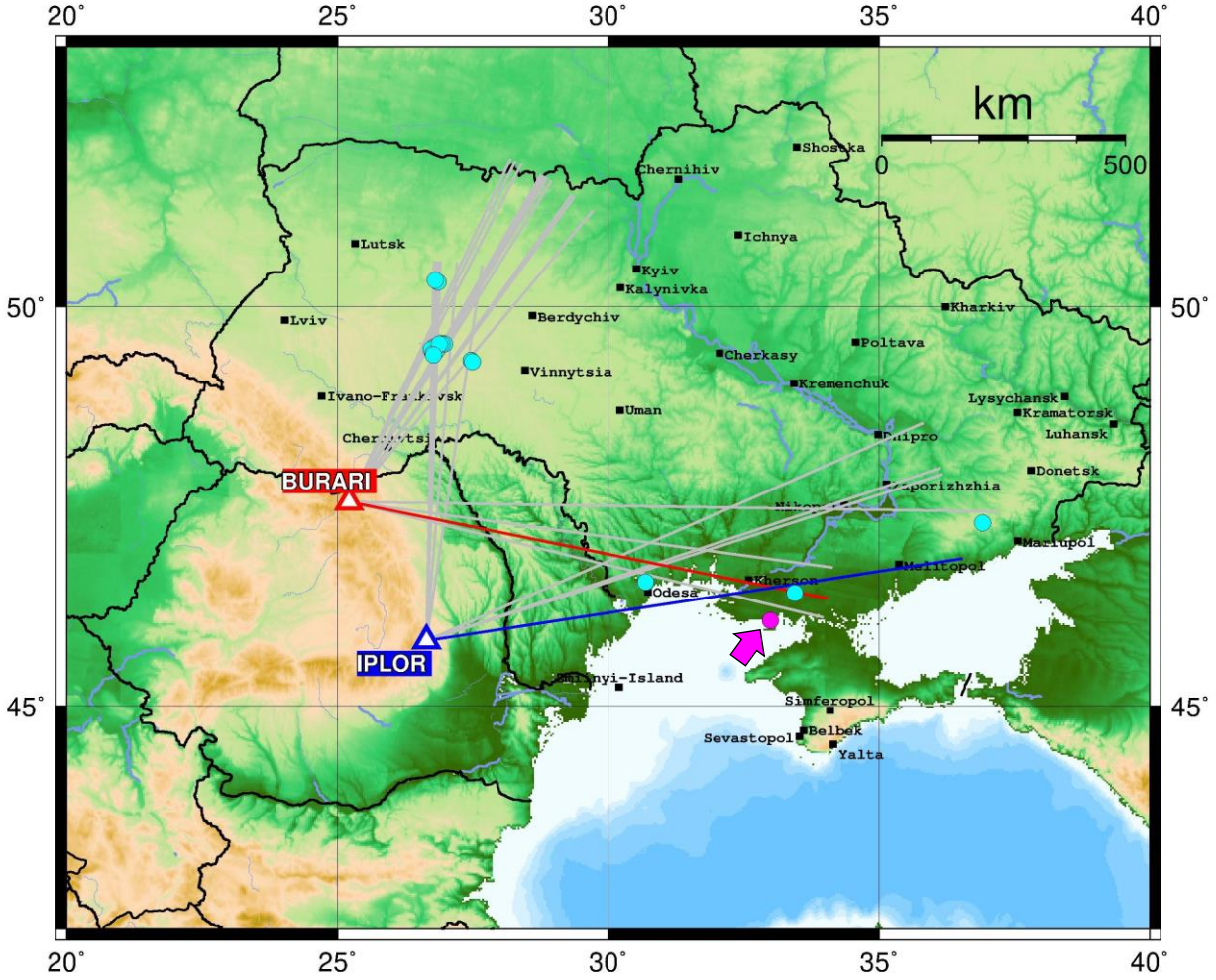
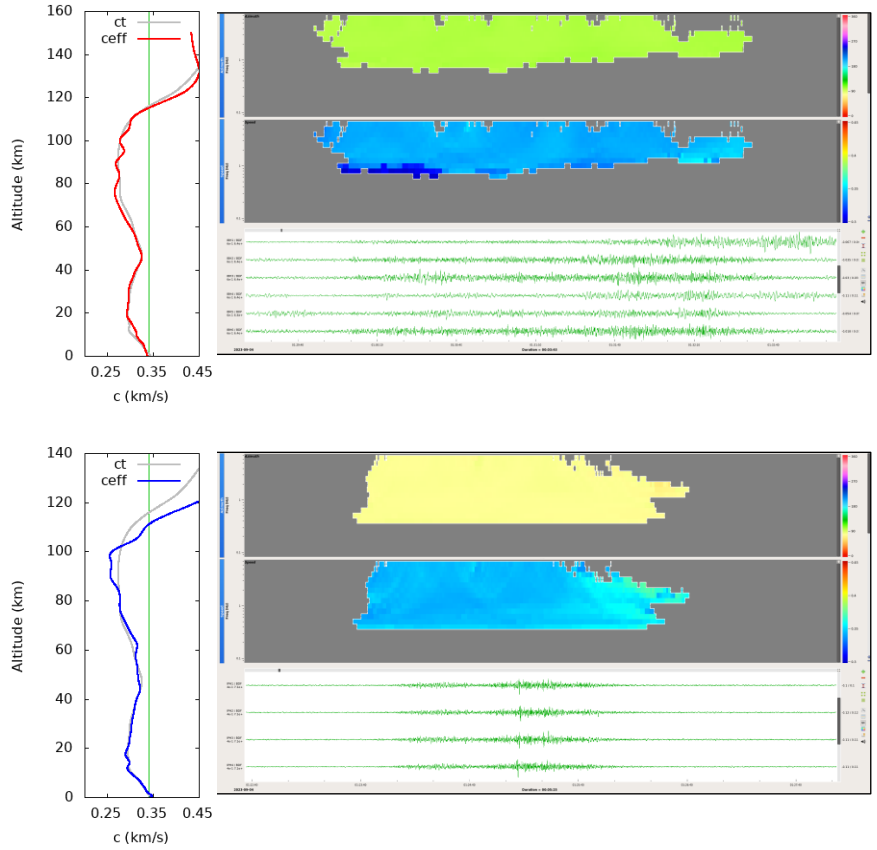
Association of infrasonic detections with LEB locations (examples)

4 September 2023, Russia claiming Ukrainian drones shot down over Black Sea

- P-P amplitude of infrasound signals: up to 0.1 Pa at BURARI and up to 0.1 Pa at IPLOR





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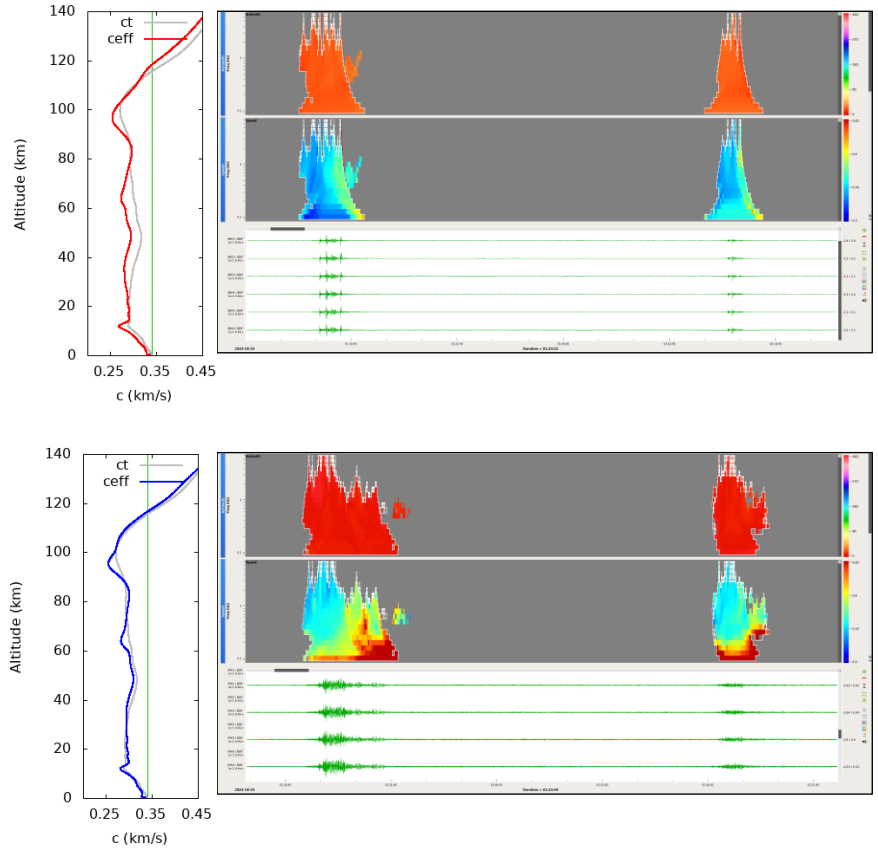
Association of infrasonic detections with LEB locations (examples)

25 October 2023, Russian drones attack on Slavuta*

- P-P amplitude of infrasound signals: up to 2.1 Pa at BURARI and up to 0.6 Pa at IPLOR
- Two LEBs associated



*"On 25 October, Russian kamikaze drones struck the Shepetivka raion of Khmelnytskyi oblast; their target was most probably the 47th Arsenal of the Main Rocket and Artillery Directorate, southeast of Slavuta" https://www.osw.waw.pl/en/publikacje/analyses/2023-10-27/strong-russian-strike-khmelnytskyi-oblast-day-610-war

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Conclusions & Future work

- Detection performance of the Romanian infrasound stations BURARI and IPLOR are permanently investigated for relevant recurrent coherent signals
- This analysis was focused on the high frequency signals (above 1 Hz) detected mainly from consistent sources related to the intense military activity caused by bombardment and shelling during the Ukraine war
- Coherent infrasound signals were automatically associated with LEB events provided by IDC/CTBTO
- The observed and expected (theoretical) values of both backazimuths and arrival times for the LEB events were compared
- Allowed deviations between observed and expected values were considered as ±10 deg for backazimuth and ±10 min for arrival time
- Approx. 25% of LEB events could be associated to BURARI infrasound detections; to IPLOR detections – 27% of these events
- Characteristics of the associated infrasonic signals, i.e., number of detections, backazimuth deviation, RMS amplitude, were analysed
- At both stations, for almost 90% of LEB associated events, the observed backazimuth values lie between 10 and 110 degrees, and almost 80% of LEB associated events are ranging between 200 and 1500 km from the arrays, likely indicating that they originate from recurrent acoustic events produced by the intense explosive military activity throughout war in Ukraine
- Several examples of strong acoustic events located on the Ukraine territory and reported in LEBs common detected by both arrays, were presented
- Analysis of detections associated to explosive sources related to the military activity started in February 2022 provides the outputs which will be used for machine learning to train neural network for explosions identification