#151

"Use of IMS Infrasound Stations for Earthquake Detection: Case Study of the February 6, 2023, Türkiye Earthquake"

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Autor:

Ana María Pérez Zeledón, MSc. (Venezuelan Foundation for Seismological Research – Funvisis)

I. ABSTRACT

On February 6, 2023, a devastating earthquake occurred in a transcontinental area located between Europe and Asia, east of Nurdagi, in the Turkish province of Gaziantep, at an estimated depth of 24.1 kilometers. This earthquake caused damage to approximately 170,000 buildings. It is one of the largest earthquakes recorded in the region in over 100 years, with a magnitude of 7.8 Mw, resulting in a regrettable death toll of more than 59,000 fatalities and 107,213 injuries. This event marks a significant turning point in global seismological research and the field of earthquake-resistant engineering, following the reported ground accelerations during the event.

In terms of energy, this earthquake released an amount 500 times greater than the energy released by the Hiroshima bomb. This paper presents the results of the analysis of the available data from the IMS infrasound stations for the detection of this event, using DTK-GPMCC.

II. Introduction

Infrasound is one of the technologies used to verify the Comprehensive Nuclear-Test-Ban Treaty. Within the framework of the verification regime, the International Monitoring System (IMS) includes a 60-station infrasound monitoring network. This network is designed to reliably detect infrasonic signals from a 1-kiloton atmospheric nuclear explosion at two or more network stations. The stations are uniformly located across the globe. Each station consists of an array of high-sensitivity microbarometer sensors arranged in an optimal configuration for detecting signals from atmospheric explosions [1] and distinguishes the signals from natural phenomena such as meteorites, earthquake, volcanic eruptions, and weather events, as well as anthropogenic phenomena like the re-entry of space debris into the atmosphere, rocket launches, and supersonic aircraft. [2]

On February 6, 2023, Türkiye and Syria were affected by two shallow and major earthquakes in Nurdağı and Ekinozu, with magnitudes of Mw 7.8 and Mw 7.5, within the geodynamic context of eastern Anatolia [3]. According to data provided by the accelerograph network operated by the Turkish Disaster and Emergency Management Authority (AFAD), peak values reached nearly twice the acceleration of gravity [4], characterizing these events as the most destructive in the region in the last 100 years. These earthquakes caused severe structural damage and collapses, as well as a high number of fatalities and injuries.

This work presents the results of the analysis of available data from the IMS infrasound stations for the detection of the first of the aforementioned earthquakes using DTK-GPMCC [5]. Key tools for event characterization and recognition are highlighted, aiming to reinforce best practices within the verification regime. Additionally, the study emphasizes the capability of IMS technologies for scientific and civil applications, while providing scenarios that contribute to the continuous monitoring of network performance within the treaty framework.

III. Methodology

After carrying out a documentary review, on the published works, with free access, this work was developed following the stage shows below:

1 Data Source Identification

- ❑ Characterize the key parameters associated with the event.
- ❑ Survey the Secure Web Portal during the designated launch window.
- ❑ Thoughtfully select appropriate infrasound stations and channels for data collection.

2 Data Extraction and Preprocessing

- ❑ Utilize the Auto NMS_Client to download data available for the select stations and time window of interest.

3 Data Processing for further analysis.

- ❑ Employ DTK-GPMCC, available within the SHI-NIAB software package, for data processing.

4 Analisys and Results Validation

- ❑ Compare the localized infrasound signals with the theoretical results associated to REB in SWP

5 Conclusions

- ❑ Draw conclusions based on the analysis.

GPMCC

IV. Results

Input = NMS_Client Data

Event:Chang Zheng-3B (CZ-3B) rocket launched from Xichang Satellite Launch Center, China

Fig. 1. 2023 Türkiye earthquake damages. (Picture take by Ascanio. W, 2023).

Survey and Data Proccesing using DTK-GPMCC

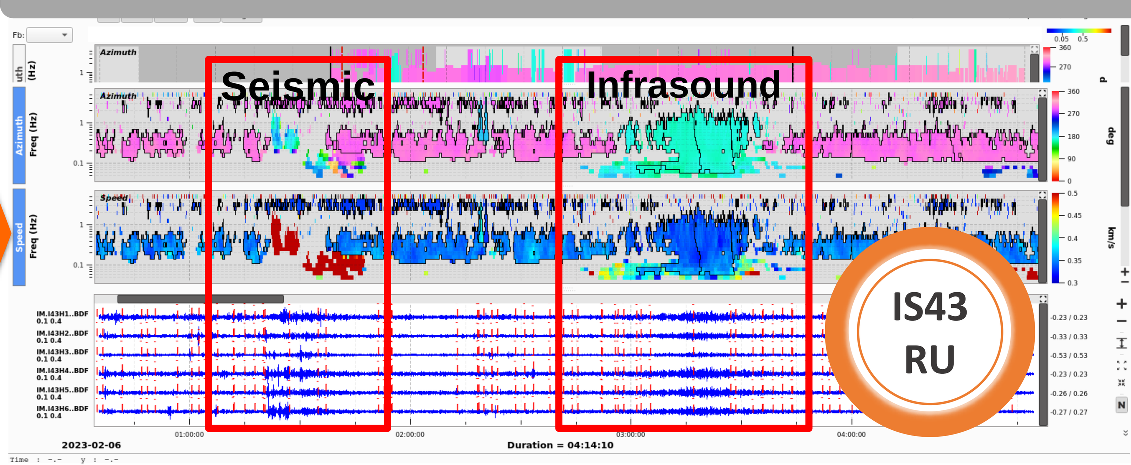

Fig. 2. GPMCC Detections for IS43RU, showing all pixels.

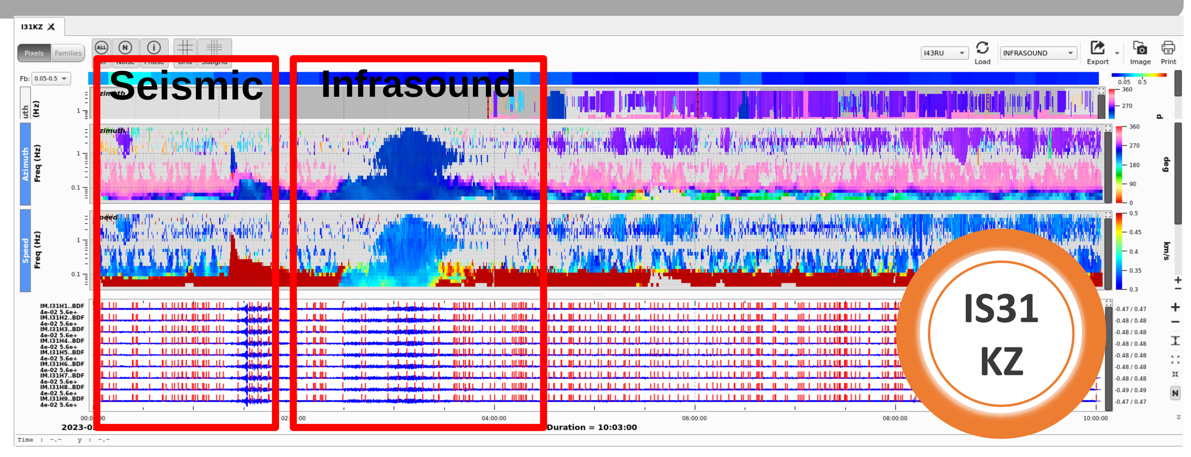

Fig. 3 GPMCC Detections for IS31KZ, showing all pixels.

Validation

REB EVENT: 23486908 TURKEY – Origen Id: 23538553[3]

Latitude	Longitude
37,2687 °	37.0891°

Data Processing DTK-GPMCC (IS43RU)

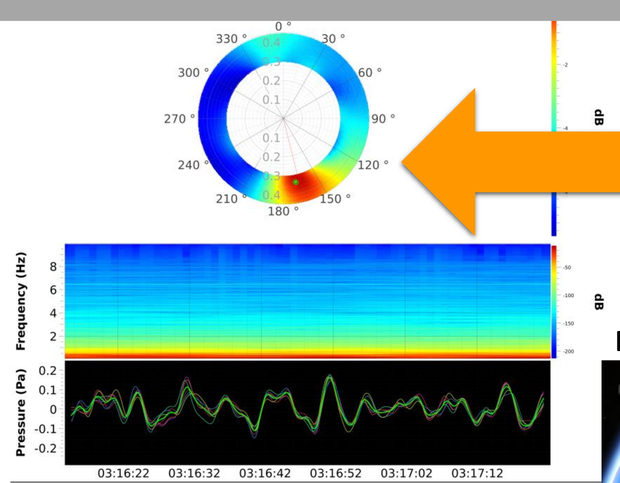

Fig. 5. FK - IS43RU.

Source location and Pixel Proyection

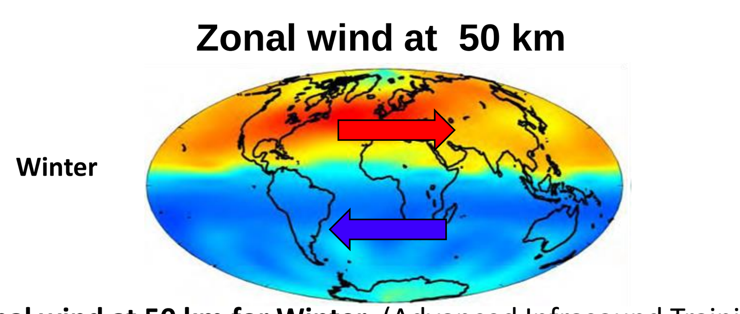

Fig. 4. Zonal wind at 50 km for Winter. (Advanced Infrasound Training. CEA, 2024).

Data Processing (IS31KZ)

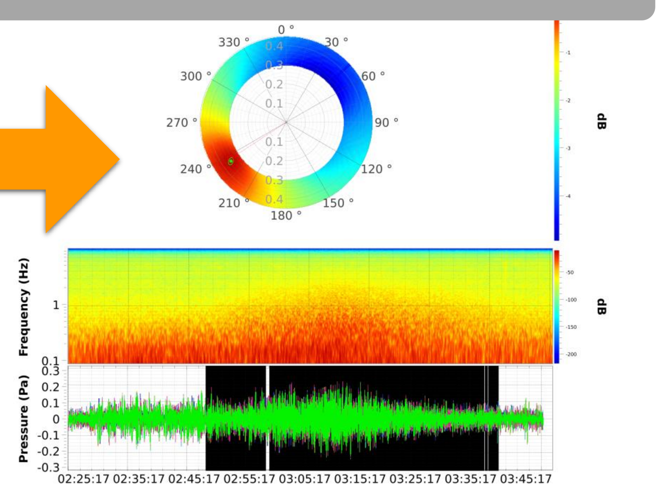

Fig. 6. FK - IS31KZ.

Analysis

Main results

The results obtained for the source location(path distance and azimuth) are consistent with the direction and distance to the associated epicenter REB Origen Id.

IS43RU	IS31KZ
Path distance: 1902.14 km Azimut: 169.3°	Path distance: 1784.32 km Azimut: 234.8°

❑ **Infrasound Celerity:**
0.302 km/s: stratospheric arrivals.

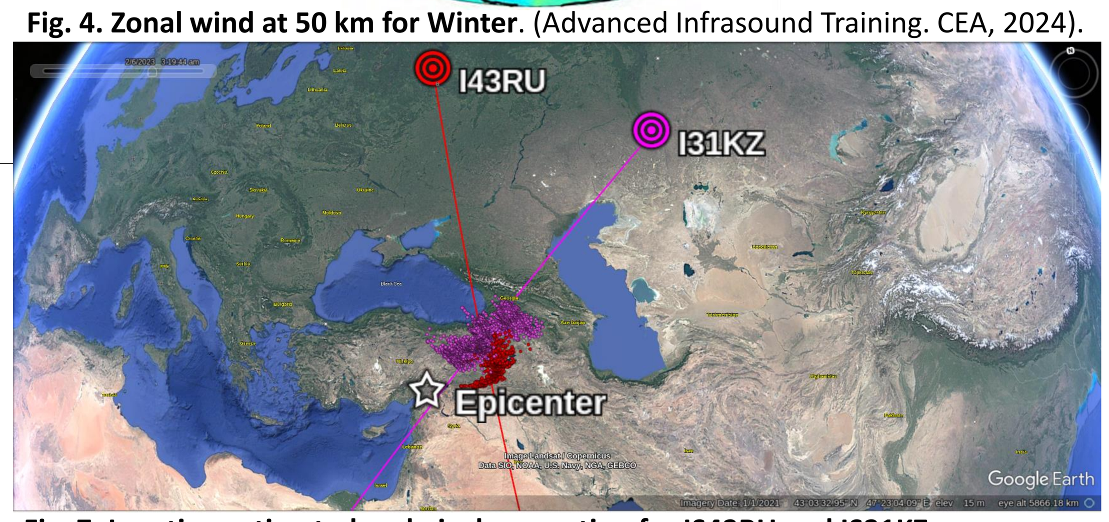

Fig. 7. Location estimated and pixel proyection for IS43RU and IS31KZ

❑ **Infrasound Celerity:**
0.309 km/s: stratospheric arrivals.
0.340 km/s tropospheric arrivals.

The estimated celerities and frequencies correspond to infrasound signals

IV. Conclusions

The DTK-GPMCC software enables the visualization of both seismic waveforms and the infrasound waves generated by seismic events. However, when implementing a 1/3 octave configuration, the pixels corresponding to seismic events can only be visualized by activating all pixels. This activation allows the observation of the arrival velocities of different seismic phases, providing comprehensive insights into the event. The tools such as Celerity Cursor, FK, Pixel Projection, and Azimuth Projection available on DTK-GPMCC are highly useful for the characterization and recognition of seismic events and various infrasound arrivals.

The analysis of selected stations for the case study has revealed that network performance is influenced by the seasonal oscillation of winds. This highlight the importance of considering environmental factors and seasons when selecting stations for event analysis or evaluating network performance and data accuracy.

Moreover, the analysis of events such as earthquakes and other natural or anthropogenic events using the tools available in the NDC in a Box package is a best practice. It enhances the performance level of National Data Centers (NDCs), preparing them for the entry into force of the treaty. It also allows for the testing of international monitoring system technologies in a controlled environment and ensures the proper calibration of the IMS stations, ensuring their optimal performance.

In the context of the verification regime, the detection of natural or anthropogenic events represents an exercise that allows the continuous evaluation and validation of the detection capabilities of the IMS stations. Incorporating this process into the analysis pipeline would enhance the system's reliability, enabling the assessment of the impact resulting from changes in the geometry of the network due to disruptions in its elements.

Overall, the use of DTK-GPMCC and NDC in a Box tools contributes significantly to the robustness and reliability of the IMS by ensuring accurate detection and analysis of potential events.

V. References

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VI. Acknowledgment

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