SnT 2025 8 SEPTEMBER ONLINE DAY 9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
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Analysis of Infrasound signals generated by bolides in South America

Letícia Guedes Assunção , Lucas Vieira Barros, Darlan Portela Fontenele, Nicolas Rainner Imanna, Juraci Mario de Carvalho, Ana Clara De Araujo Sousa

TMc Student / University of Brasília / Seismological Observatory

Presentation Date: 11 September 2025

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Outline

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Introduction

IMS Infrasound Stations

- Operated by CTBTO, designed for nuclear test monitoring.
- Also detect natural and anthropogenic events (e.g., bolides).

Undergraduate Research

- Analysis of bolides detected by IMS stations in South America (2018–2025).
- Data source: NASA CNEOS catalog.

Case Studies

- Two events: 2019 and 2022.
- Energy < 1 kt TNT.

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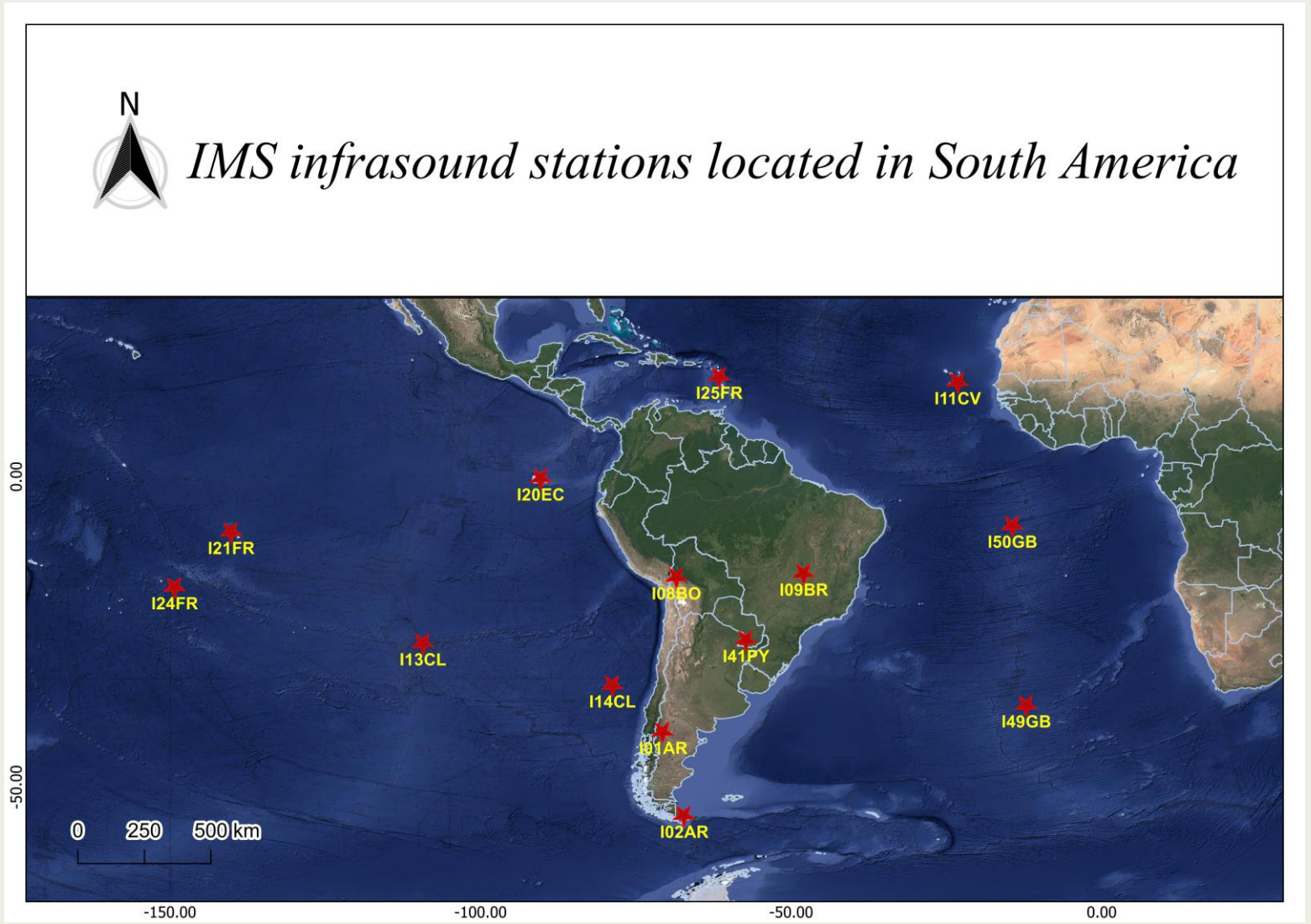

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Scientific Context

How is infrasound generated?

Modified from the American Meteor Society (American Meteor Society, 2025).

Meteoroids in the Atmosphere

- Fragments of asteroids or comets.
- Produce visible phenomena: meteors, fireballs, bólides.
- Classification depends on mass, velocity, and energy.

Infrasound Production

- Atmospheric entry generates shock waves.
- Shock waves propagate as infrasound (<20 Hz).

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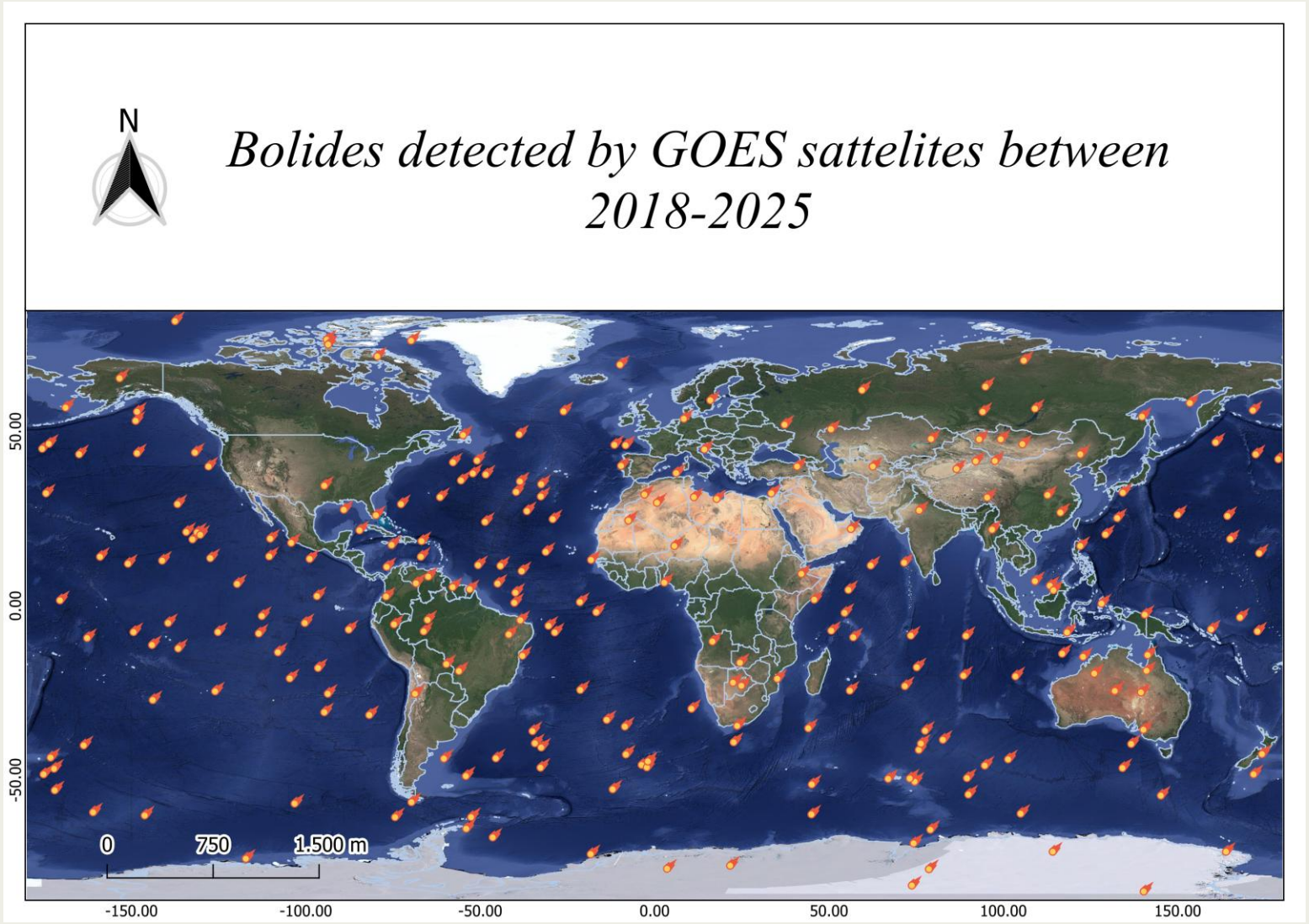
Methodology



- ***Data Source***: CNEOS database
- ***Detection System***: GLM sensors onboard GOES satellites.
- ***Time Period***: 2018 – 2025
- ***Data Collected***: 263 bolide events recorded worldwide.
- ***Purpose***: Analyze global distribution and characteristics of bolide events.

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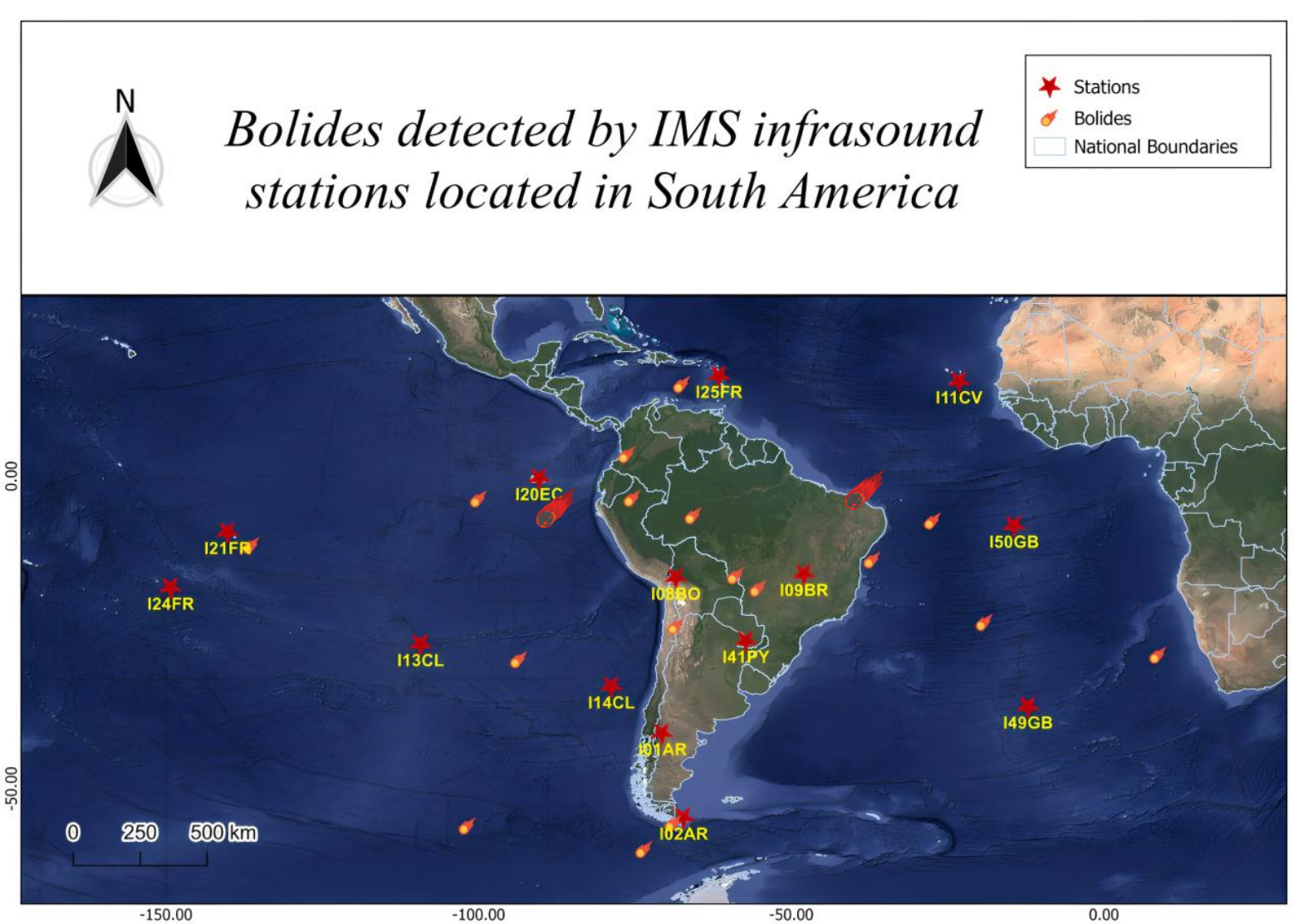

- 263 bolides (2018–2025) recorded globally.
- 19 detected by IMS infrasound stations in South America, 14 in SEL-3 Bulletin and 5 via waveform analysis.
- **Case Studies**: Dec 6, 2019 (Brazil) & Jul 28, 2022 (Pacific).
- **IMS Infrasound Stations**: I20EC (Ecuador), I08BO (Bolivia), I09BR (Brazil), and I41PY (Paraguay).
- Analysis with **DTK-GPMCC**: direction, speed, frequency and signal duration.

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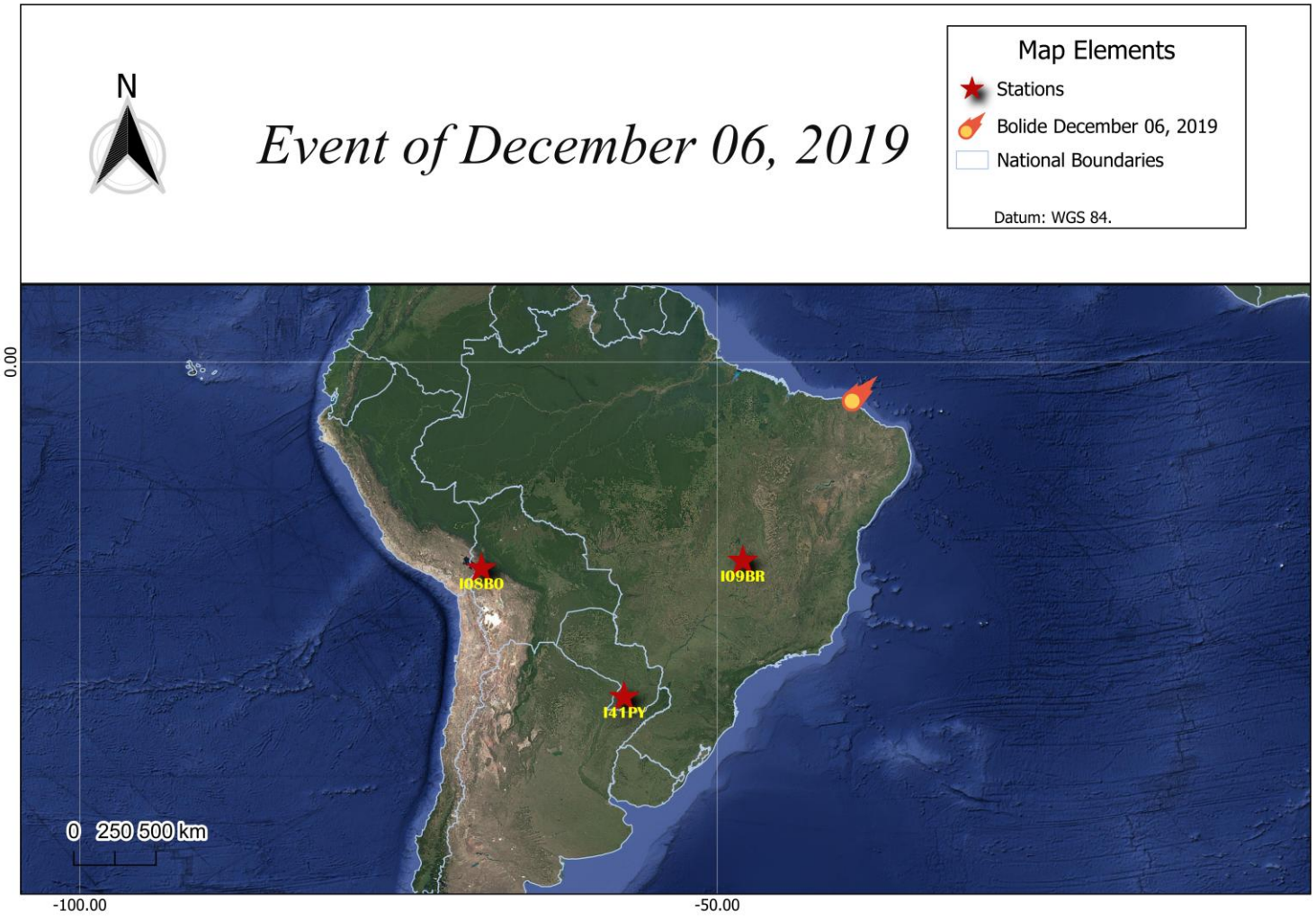
Data Analysis and Results

Event of December 6, 2019



Bolide Event – Fortaleza, Brazil

- Detection time: 10:28 UTC (CNEOS).
- Altitude: ~19.5 km (CNEOS).
- Energy released: ~0.15 kt TNT (CNEOS).

IMS infrasound detections:

- I09BR (Brazil)
- I41PY (Paraguay)
- I08BO (Bolivia).

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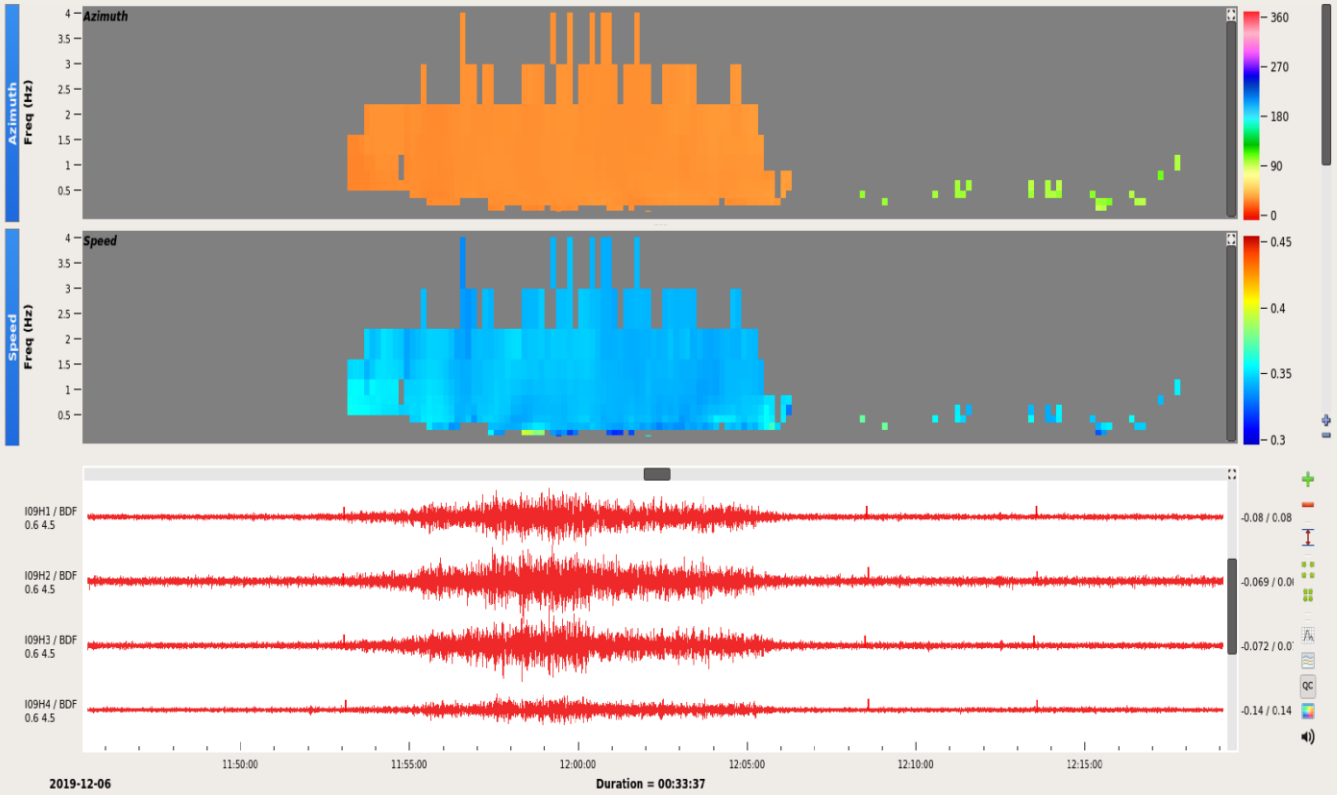
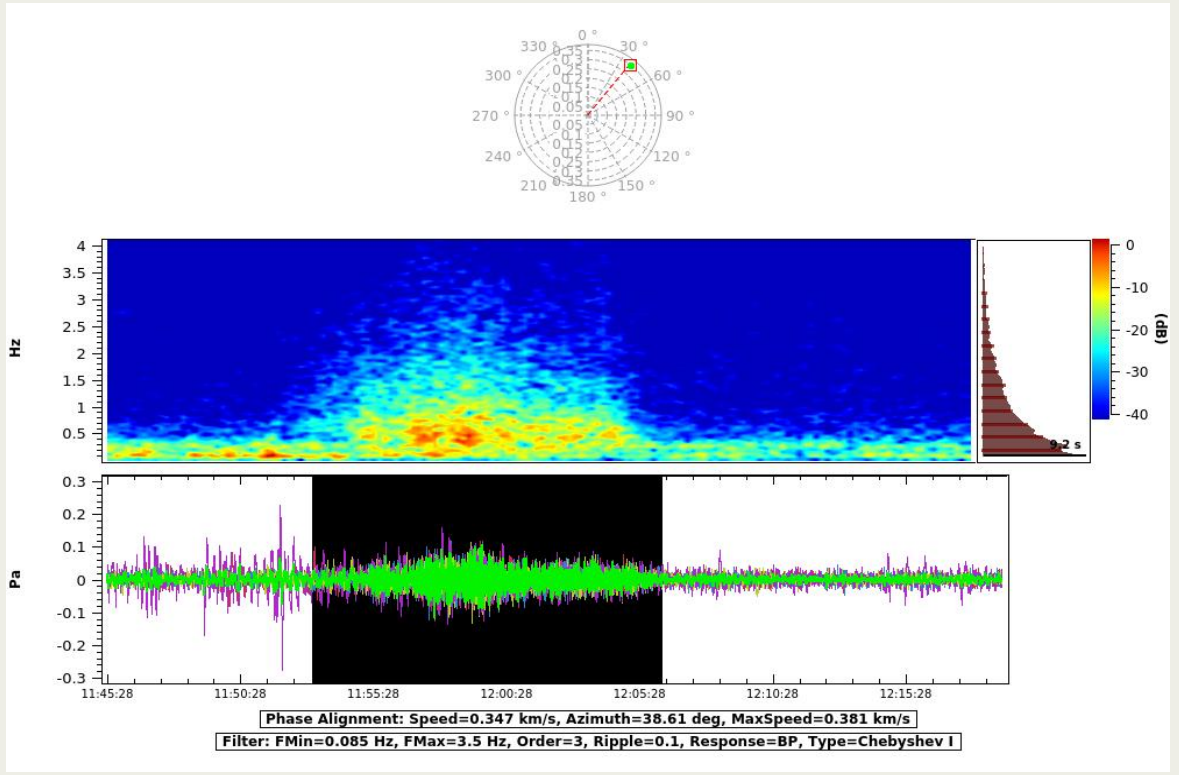
I09BR Station





I09BR → closest station, ~1,800 km.

- **Waveform** → arrival at 1h27min, duration ~13 minutes.
- **Spectrogram** → energy 0.3–1 Hz, peak at 0.5 Hz (stratospheric range).
- **Back-azimuth (39°)** → source Direction.
- **Apparent velocity (0.346 km/s)** → confirms stratospheric propagation.

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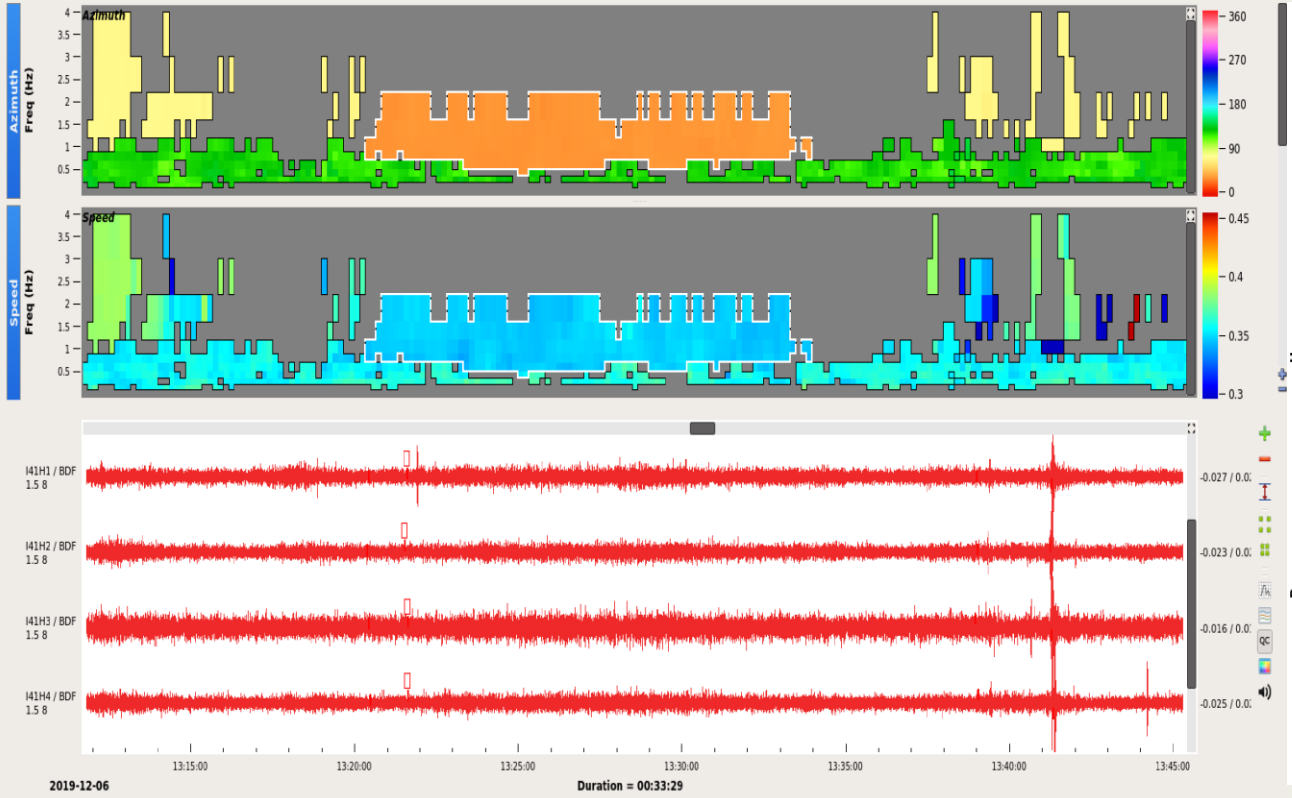
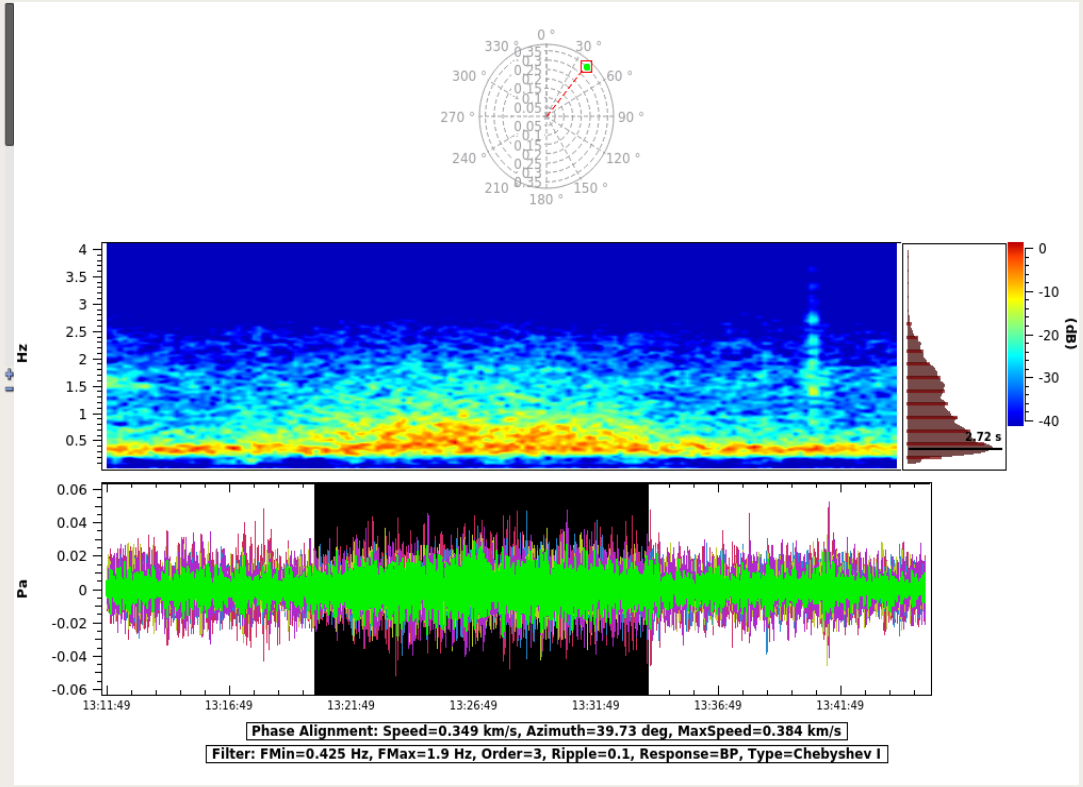
I41PY Station





I41PY → second station, ~3,300 km

- **Waveform** → arrival at 2h41min, duration ~14 minutes
- **Spectrogram** → energy 0.3–1 Hz, peak at 0.7 Hz (stratospheric range)
- **Back-azimuth (39°)** → source direction
- **Apparent velocity (0.349 km/s)** → consistent with stratospheric propagation

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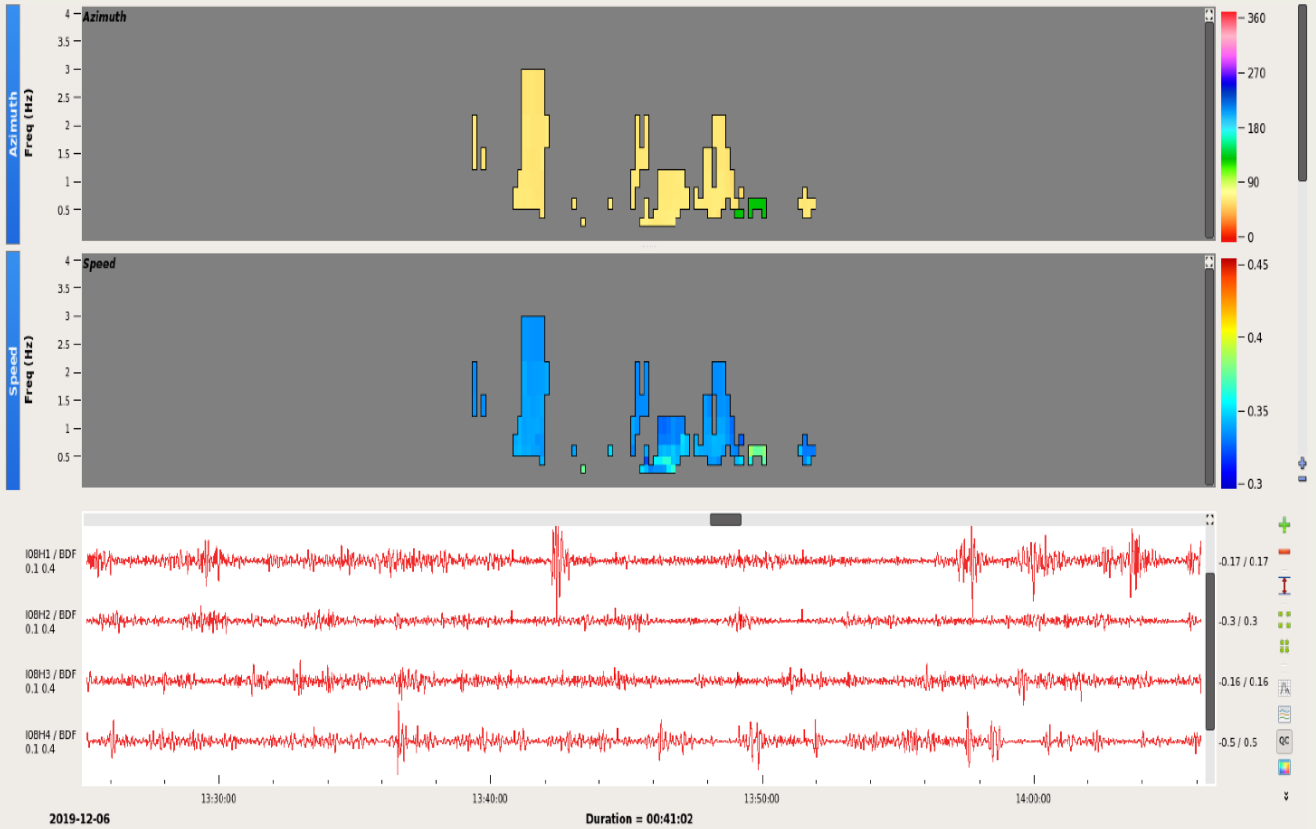
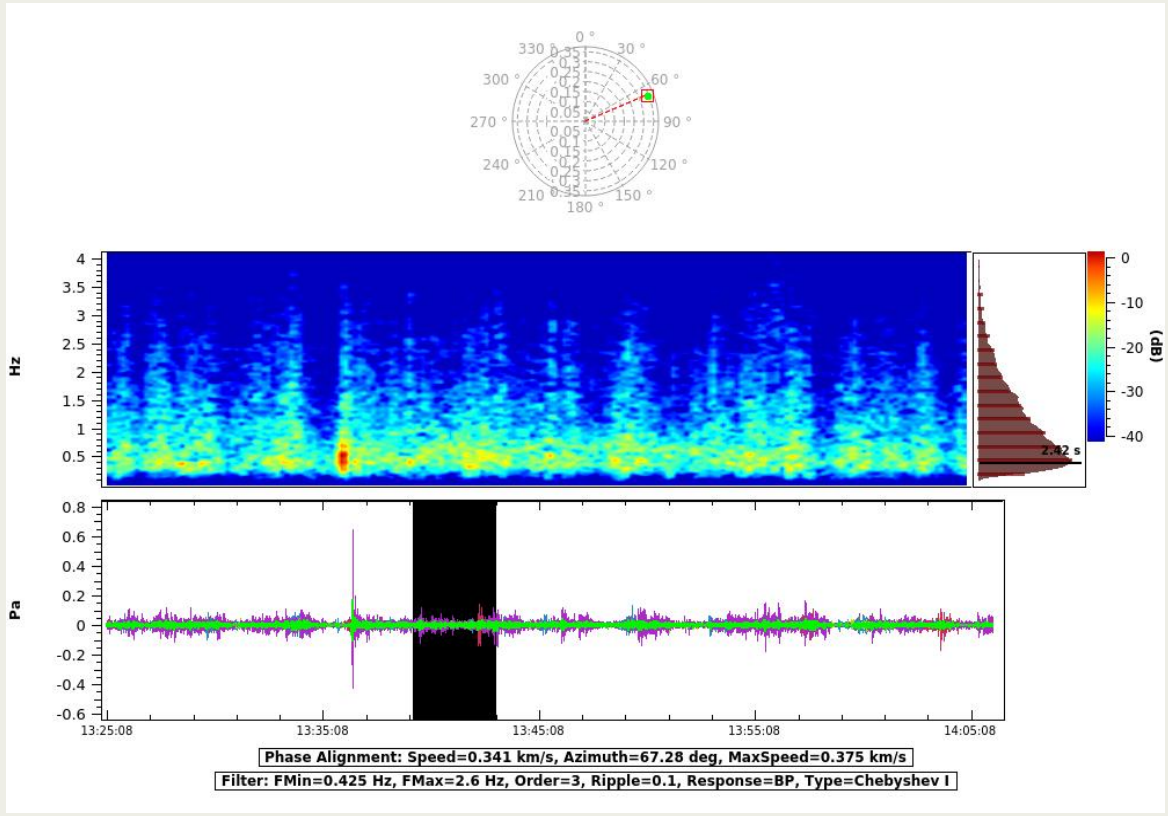
I08BO Station





I08BO → most distant station, ~3,600 km

- **Waveform** → arrival at 2h57min, duration ~6 minutes.
- **Spectrogram** → weak signal, energy around 0.5 Hz .
- **Back-azimuth (68°)** → source Direction.
- **Apparent velocity (0.341 km/s)** → consistent with stratospheric propagation.

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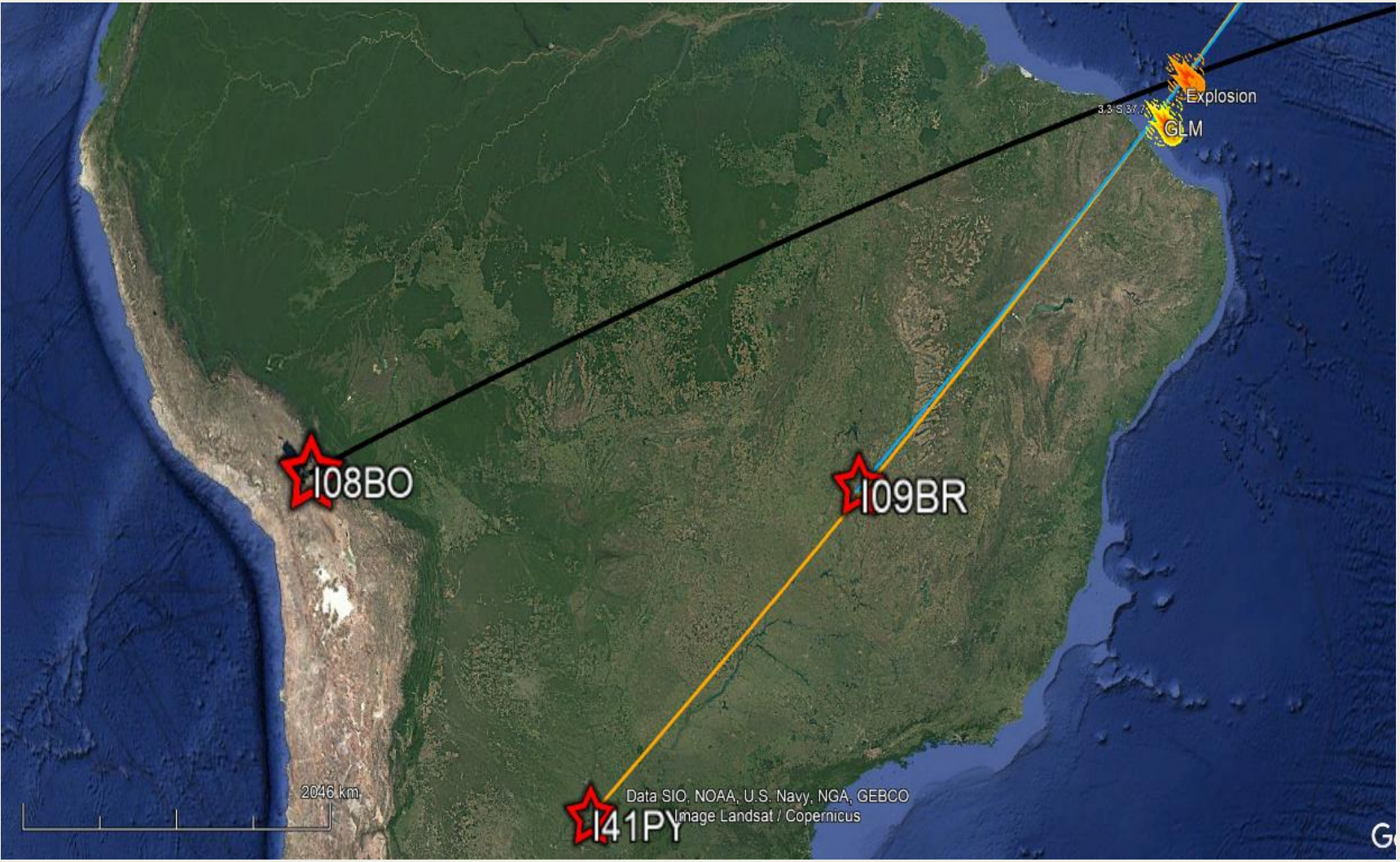
Localization



Based on the back-azimuths from the three IMS stations, the location of the atmospheric explosion was estimated as:

- **Latitude: 1.6° S**
- **Longitude: 36.8° W**

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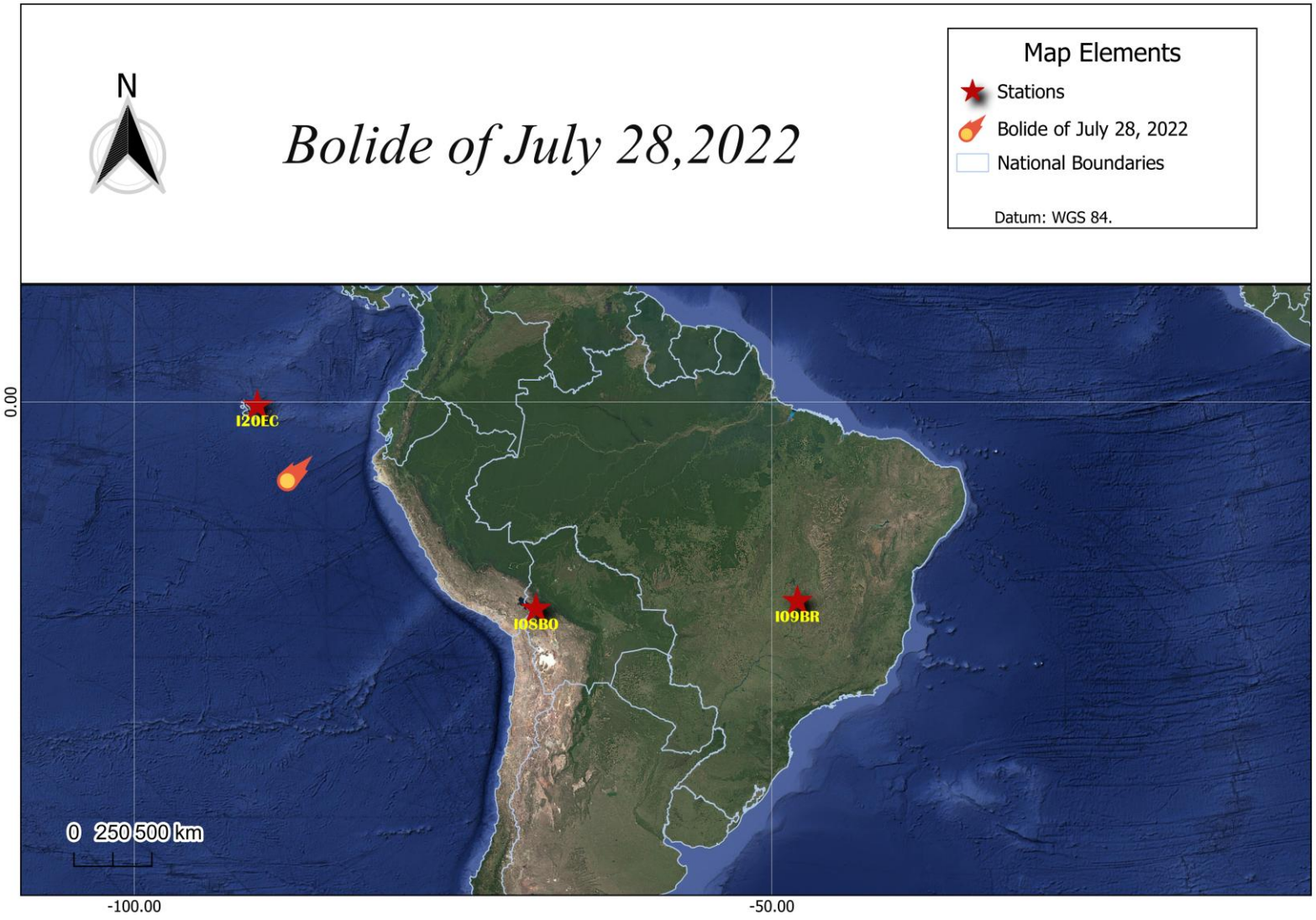
Data Analysis and Results

Event of July 28, 2022



***Bolide Event**: Southeast of the Galápagos Islands.*

- **Detection time**: 01:36 UTC.
- **Altitude**: ~37 km.
- **Velocity**: ~30 km/s.
- **Energy released**: ~0.68 kt TNT.

IMS infrasound detections:

- Ecuador, Bolivia and Brazil.
- Signal tracked up to: 4,000 km

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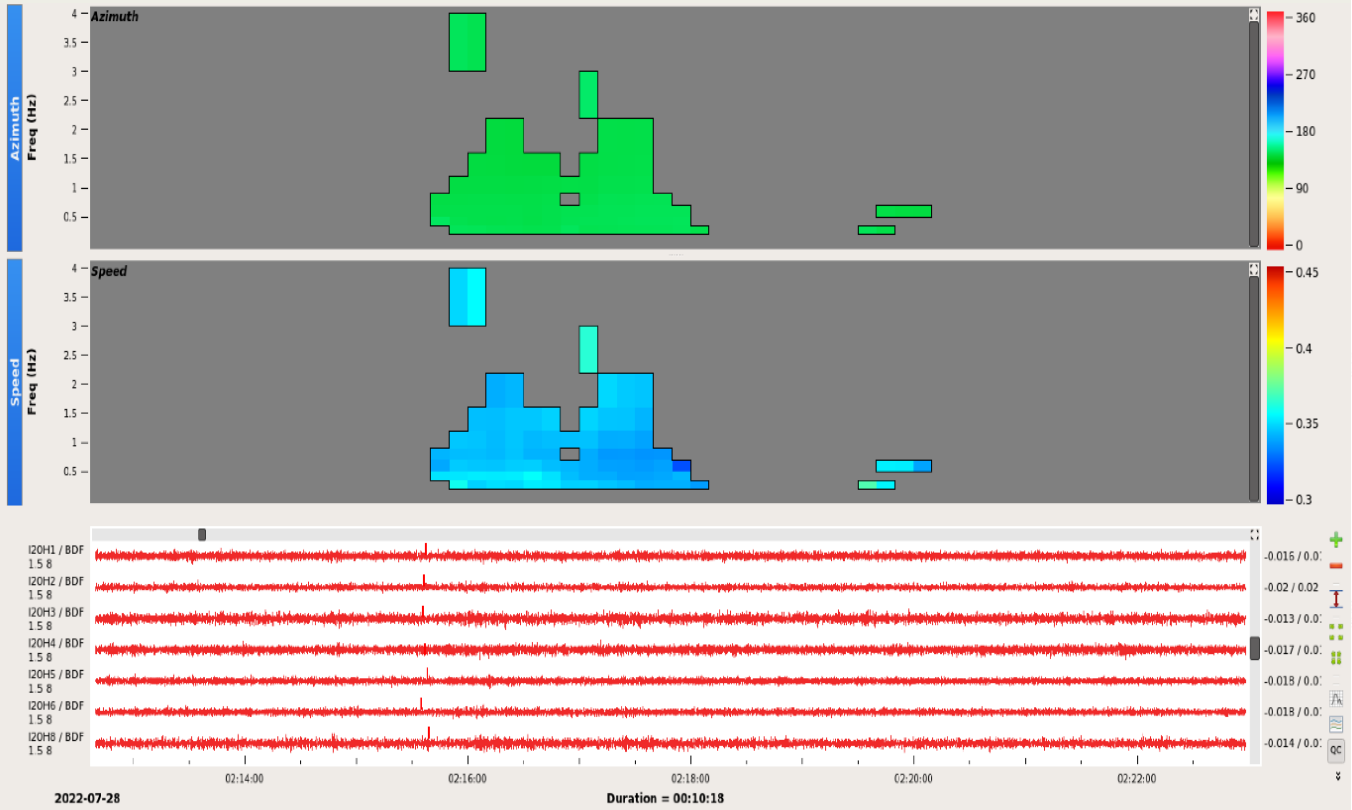
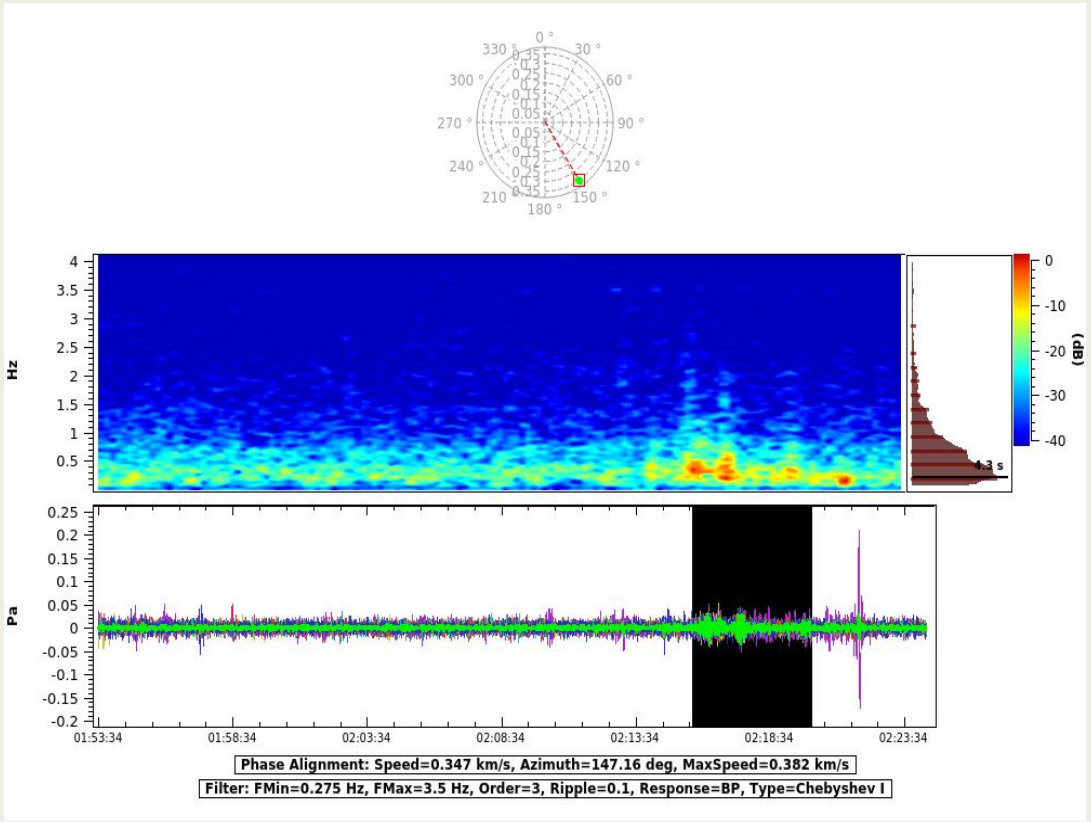
Station I20EC





I20EC → closest station, ~670 km

- **Waveform** → arrival 39 minutes after GLM, duration ~4.7 minutes
- **Spectrogram** → energy 0.3–0.5 Hz, peak at 0.5 Hz
- **Apparent velocity** → 347 m/s
- **Propagation** → tropospheric (lower atmosphere)

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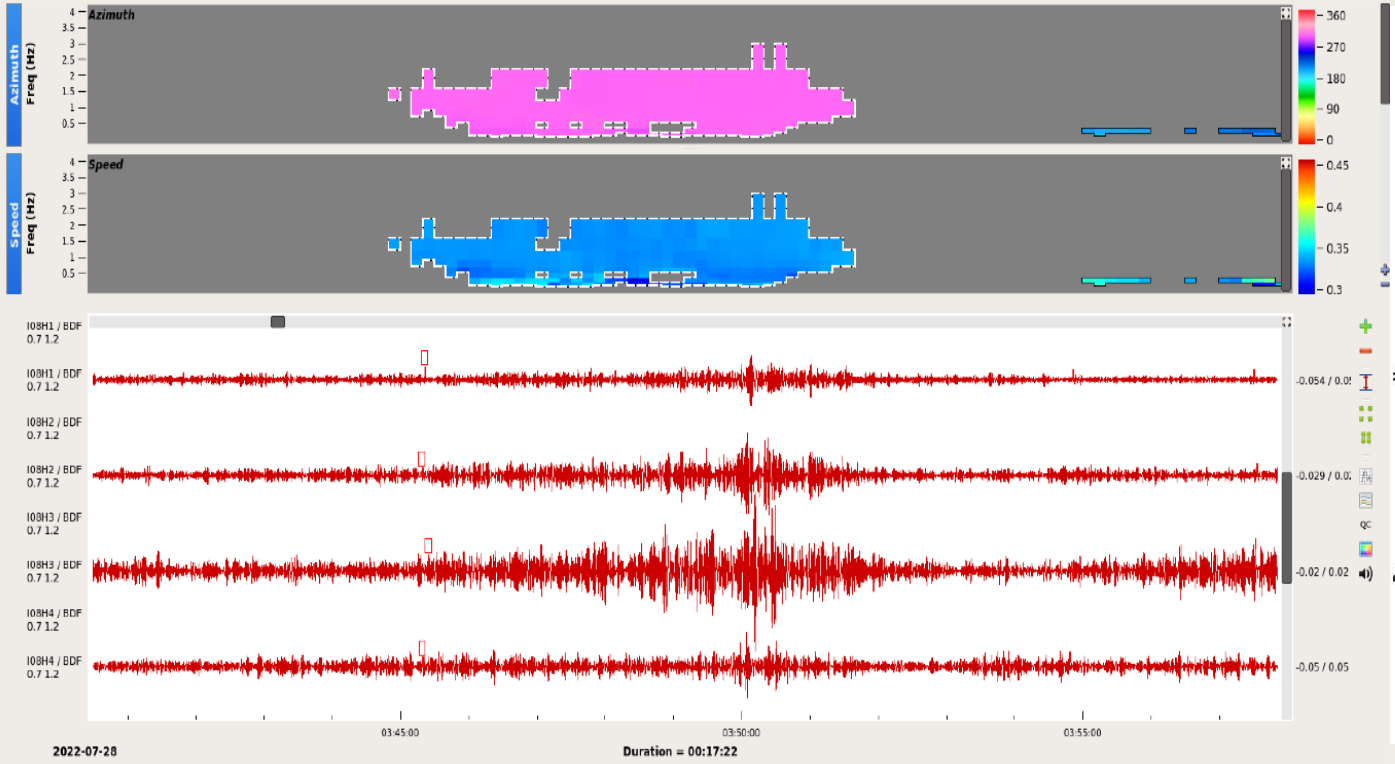
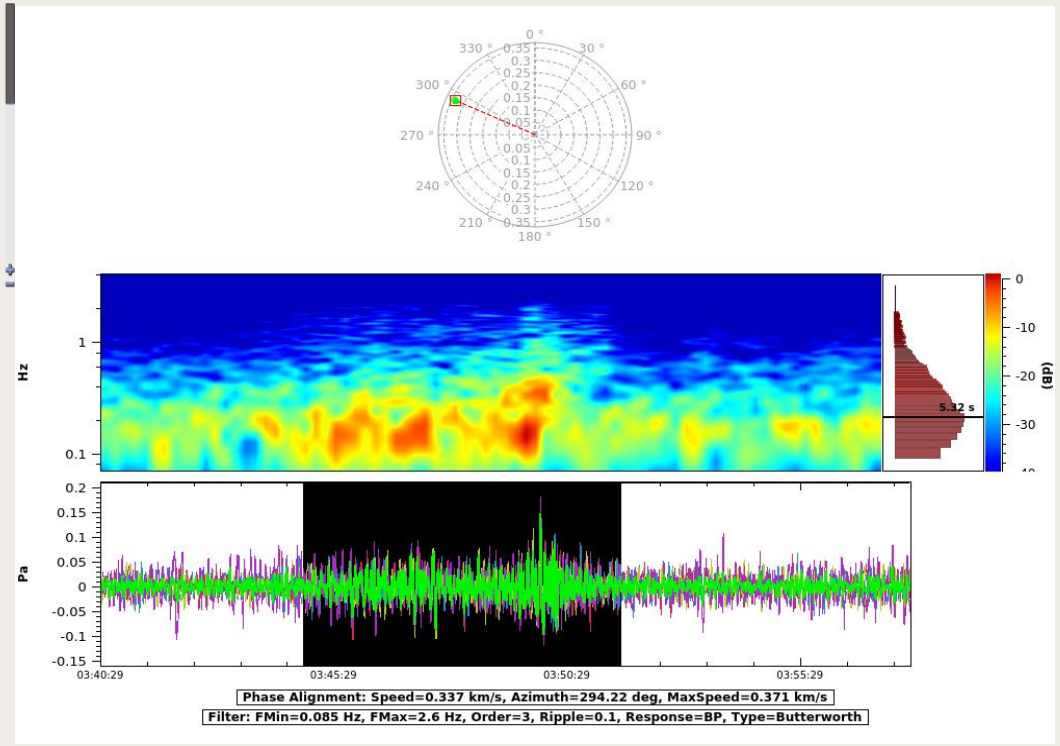
Station I08BO





I08BO → second closest station, ~2,378 km.

- **Waveform** → arrival ~2 hours after bolide, duration ~7 minutes.
- **Spectrogram** → energy 0.1–0.6 Hz, dominant 0.4 Hz.
- **Apparent velocity** → 0.337 km/s.
- **Back-azimuth** → 294°.
- **Propagation** → stratospheric (upper atmosphere, long distance).

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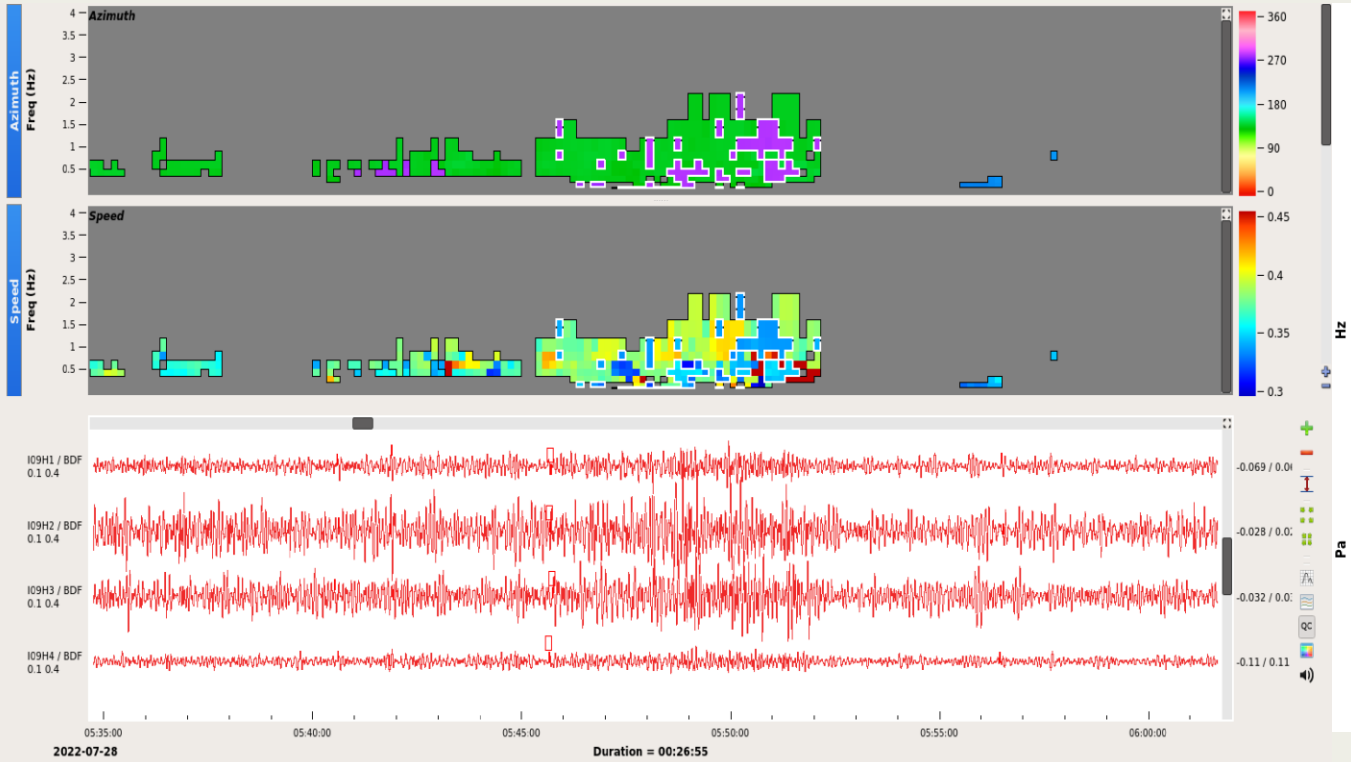
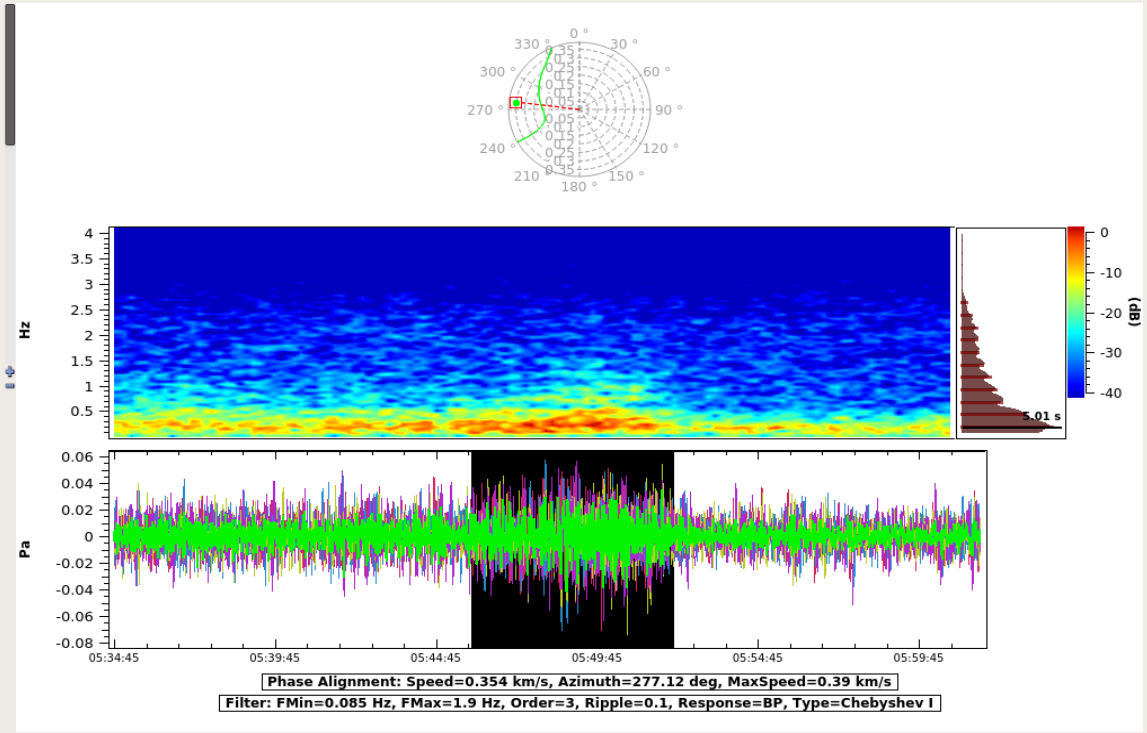
Station I09BR





I09BR → most distant station, ~4,450 km

- **Waveform** → two signal families:
  - 277°, duration ~6.5 minutes, apparent velocity 0.354 km/s (matches true azimuth) ; 137° → not consistent with bolide
- **Spectrogram** → energy at 0.56 Hz, band 0.2–0.6 Hz
- **Propagation** → stratospheric (over 4,000 km).

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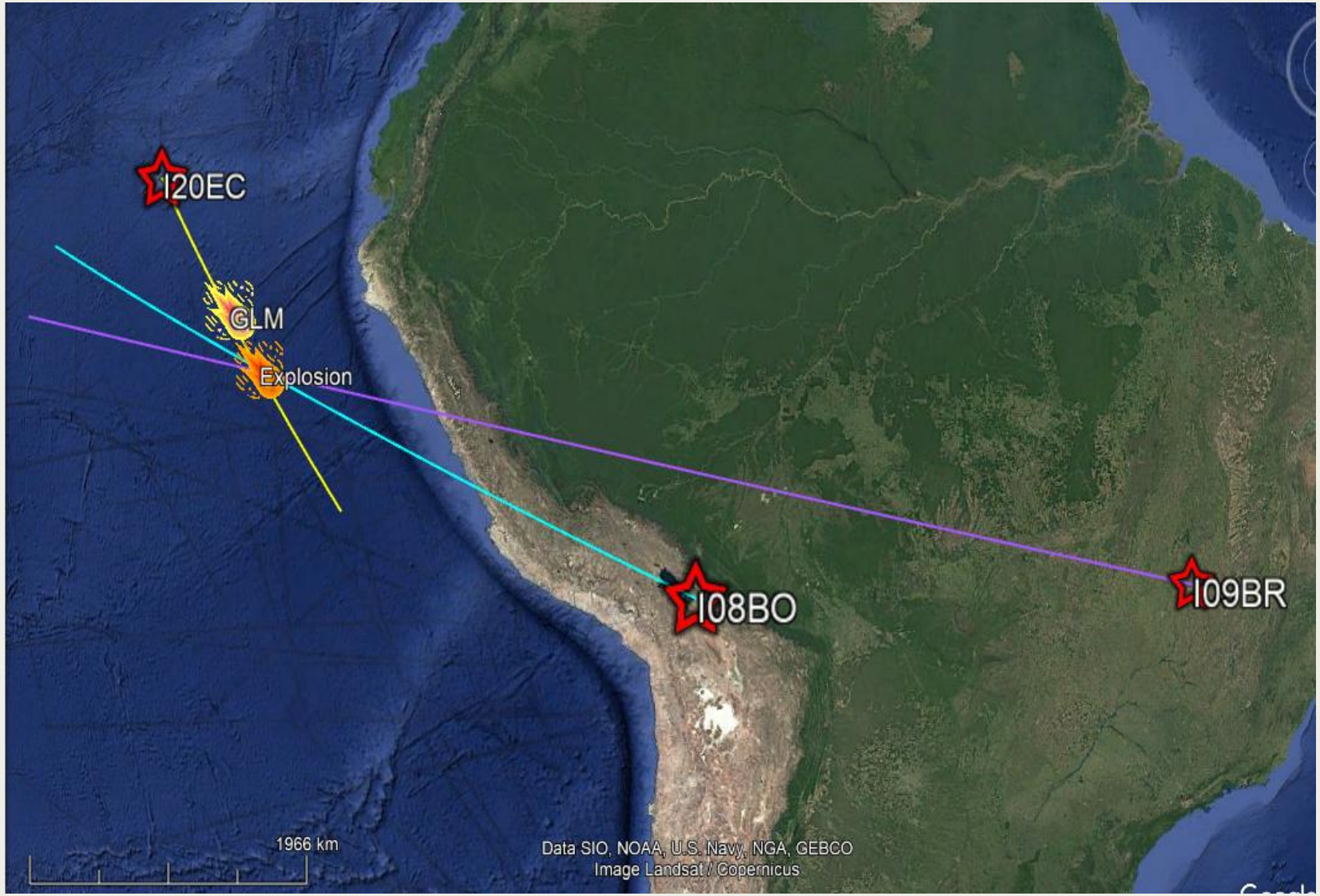

The estimated coordinates are:

Latitude: 8.1° S
Longitude : 85.4° W

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Discussion and Conclusions

Bolide Event Analyses – Dec 2019 & Jul 2022

- IMS infrasound stations detect low-energy meteoroids over vast distances.

Propagation:

- 2019 → mostly stratospheric.
- 2022 → tropospheric + stratospheric paths.
- Consistent with GLM sensor data → validates IMS detection method.
- Demonstrates IMS potential for global meteoroid monitoring.