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Method for Estimating the Tripartite Array Back-Azimuth Error Caused by the Far-Field Approximation

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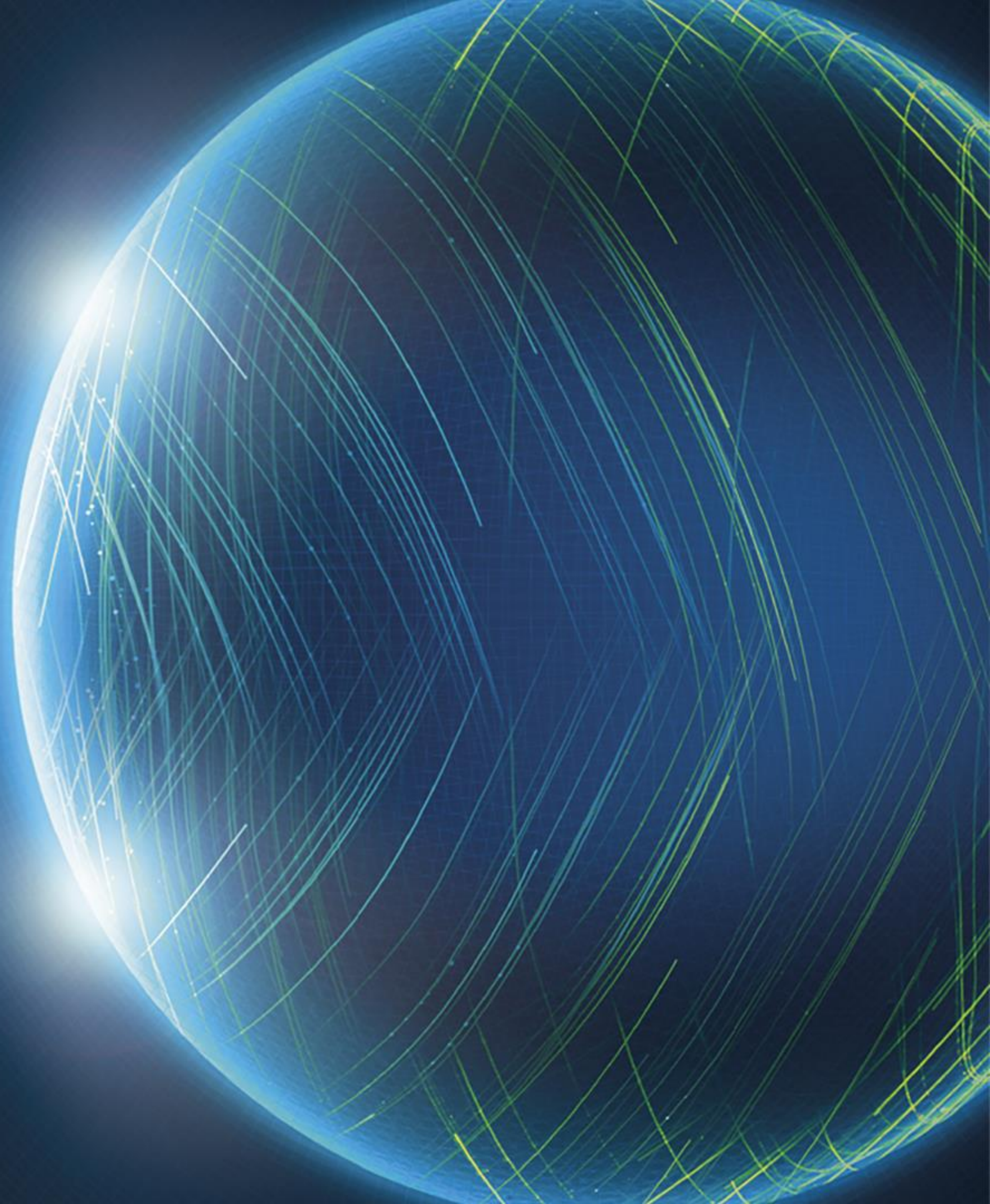

Outline

1. Motivation.
2. Back azimuth plane wave error formulas.
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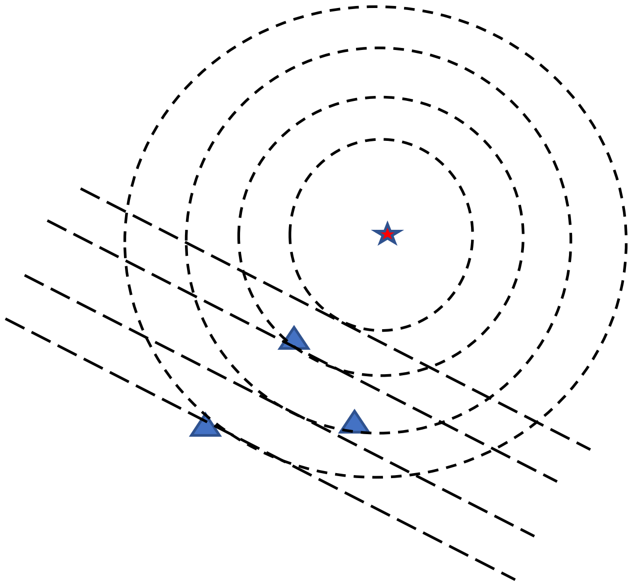
5. Summary.

Method for Estimating the Tripartite Array Back-Azimuth Error Caused by the Far-Field Approximation

- **The tripartite micro arrays became a major tool for the passive seismic phase of the On-site inspection.**
- **Up to 50 micro arrays ⟶ distances ~ 5 km ⟶ magnitude ≥-2.**
- **Many events would be detected and located by a single array.**
- **Back azimuth estimation ⟶ far field approximation.**

The far field approximation may brake

Biased back azimuth estimation



Example: IFE14 in Jordan

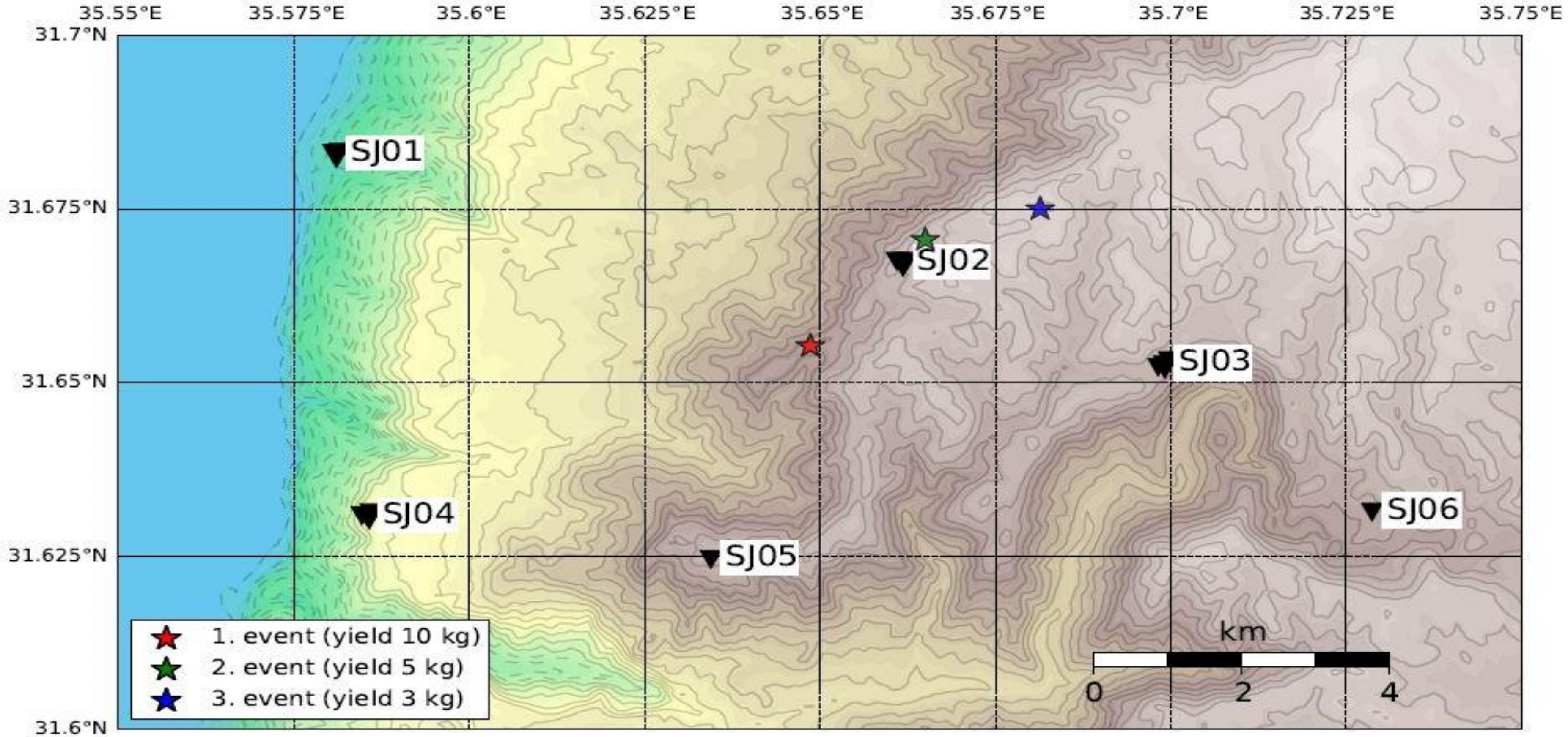


Figure from Sick et al., SnT 2015, T3.4-O2

Back azimuth formula

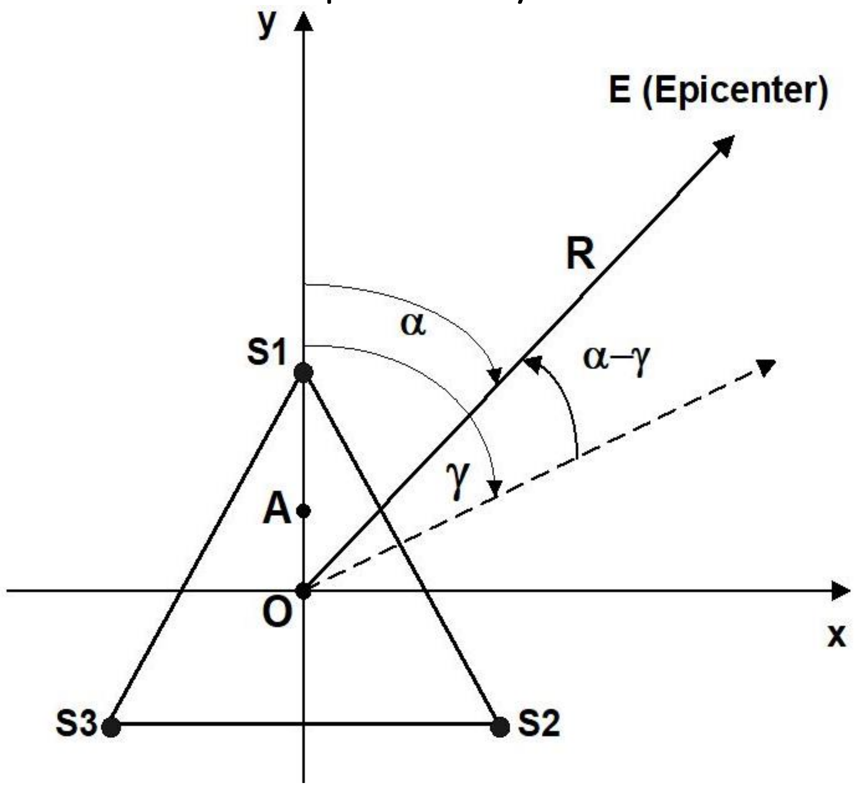
$$\cot(\gamma) = \frac{x_{12}t_{13} - x_{13}t_{12}}{y_{13}t_{12} - y_{12}t_{13}}$$

S_i [x_i, y_i] - station

x_{ij}, y_{ij} – station coordinate differences,

t_{ij} – arrival time differences (i,j=1,2,3)

Tripartite array



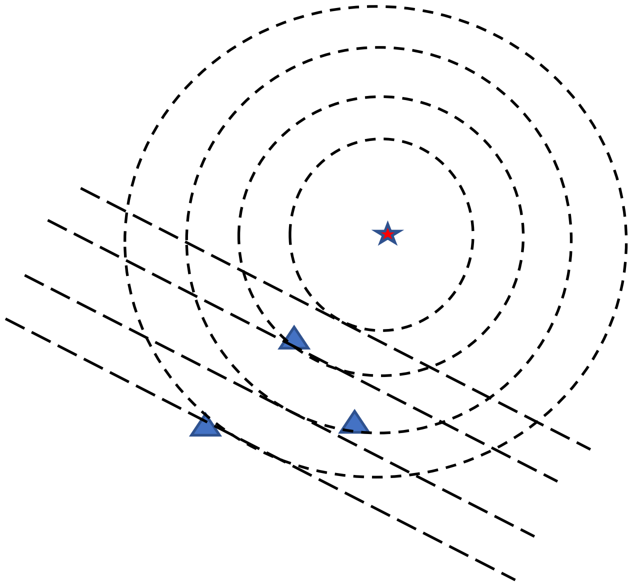
α - true back azimuth angle

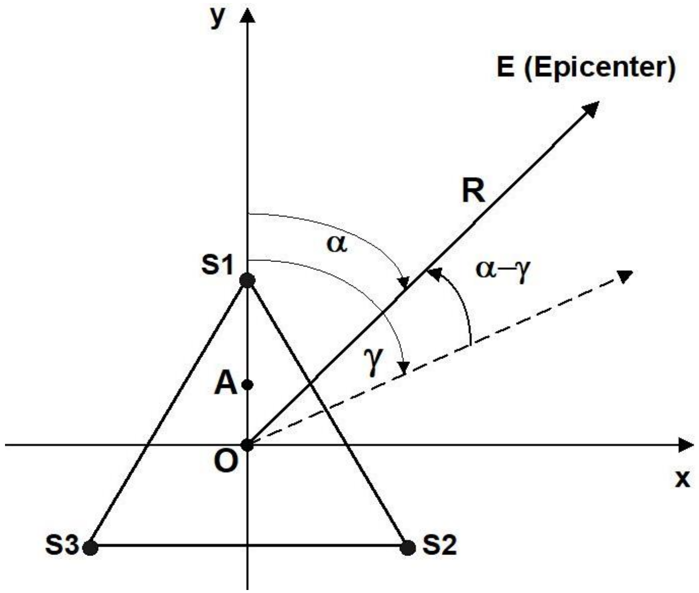
γ - back azimuth angle computed under the far field assumption

γ- α is defined as the **back azimuth plane wave error**

Back azimuth plane wave error formula:

$$\sin(\gamma-\alpha)=\frac{t_{12}(x_3^2+y_3^2)-t_{13}(x_2^2+y_2^2)-t_{32}(x_1^2+y_1^2)+t_{12}t_{13}t_{32}v_a^2}{2R\cdot\sqrt{(x_{12}t_{13}-x_{13}t_{12})^2+(y_{12}t_{13}-y_{13}t_{12})^2}}$$



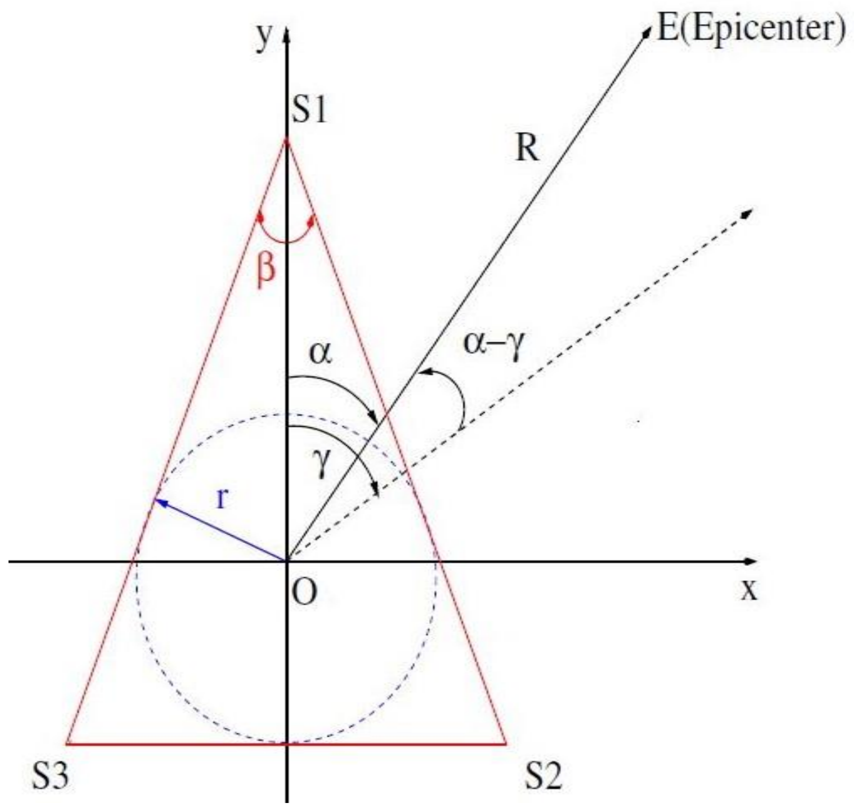


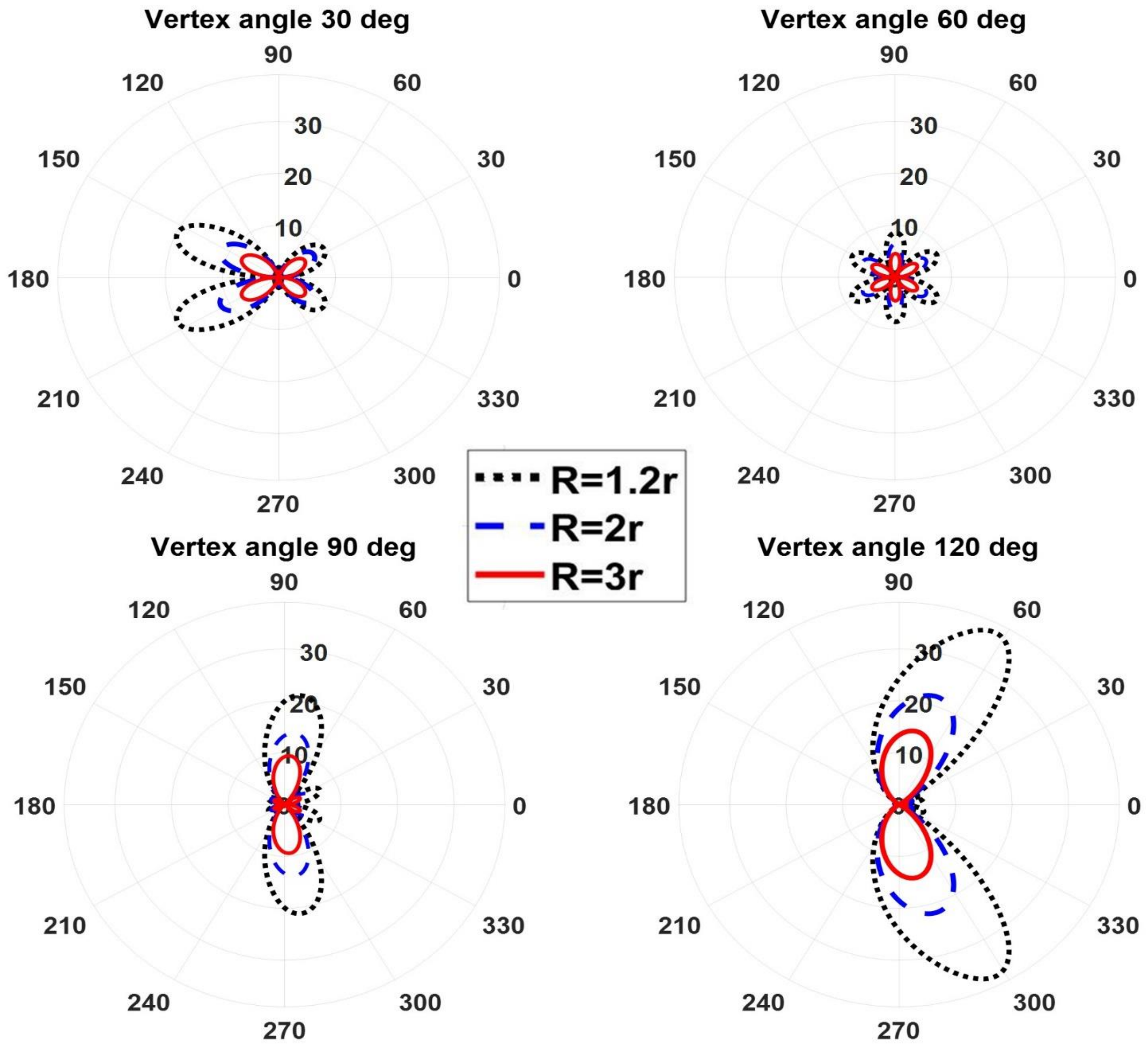
Back azimuth plane wave error properties :

- Dependent on R (epicenter distance).
- Independent of the Va (wave front apparent velocity).
- Invariable under similarity transformation applied simultaneously to the locations of the seismic stations, the reference point, and the epicenter.

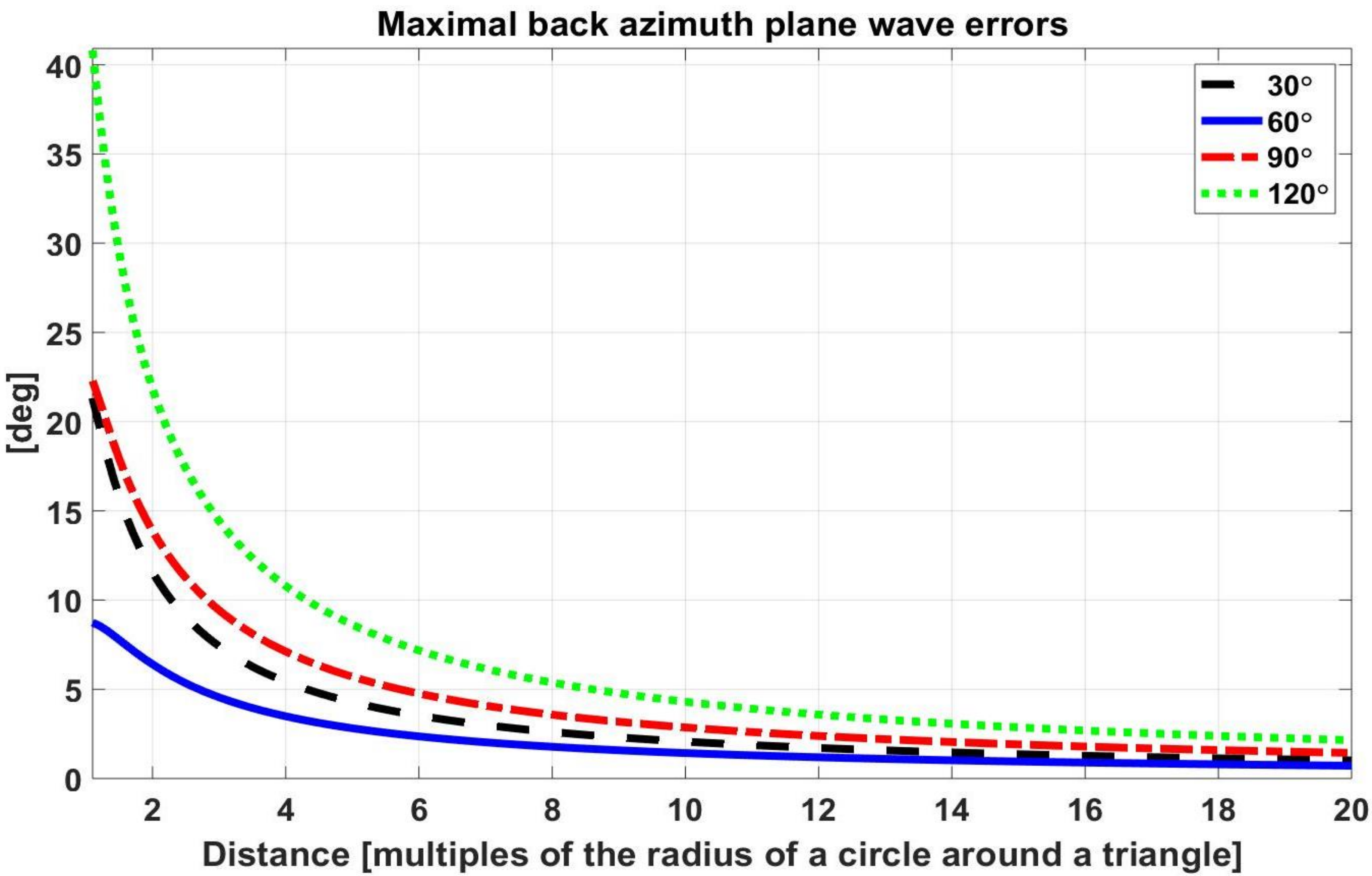
$$\sin(\gamma-\alpha)=\frac{t_{12}(x_3^2+y_3^2)-t_{13}(x_2^2+y_2^2)-t_{32}(x_1^2+y_1^2)+t_{12}t_{13}t_{32}v_a^2}{2R\cdot\sqrt{(x_{12}t_{13}-x_{13}t_{12})^2+(y_{12}t_{13}-y_{13}t_{12})^2}}$$

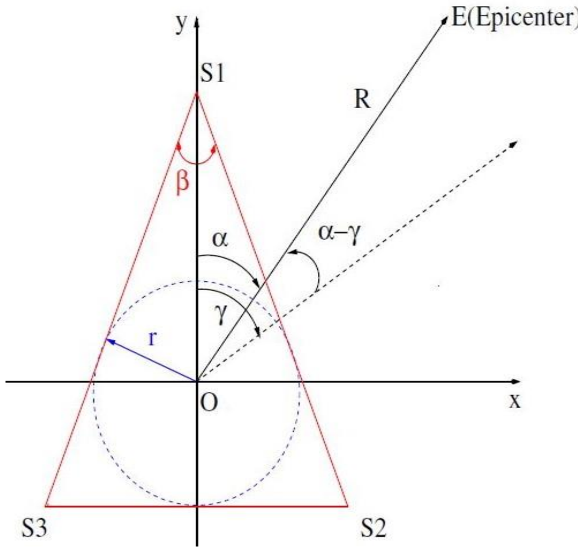
Theoretical Examples





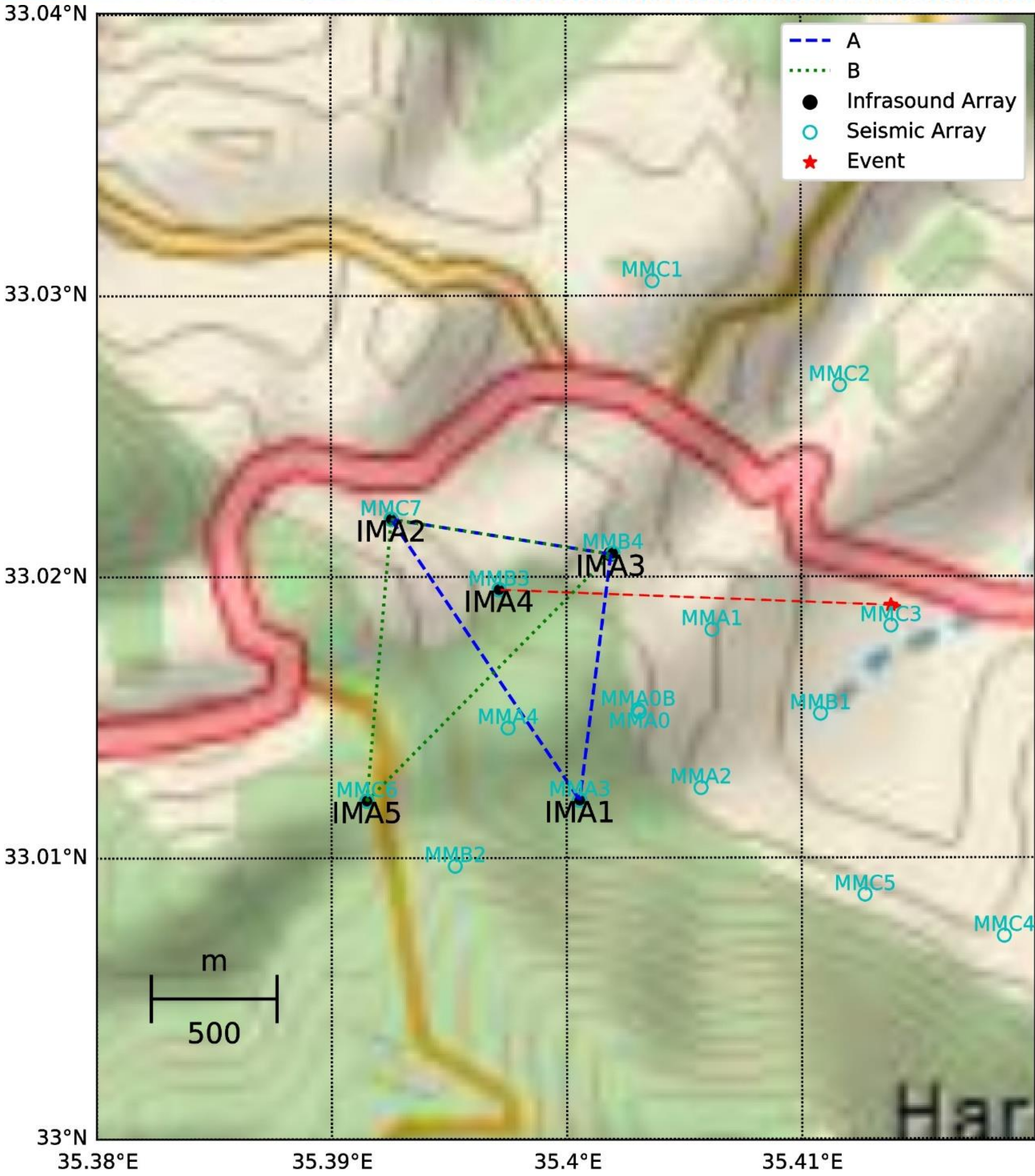
Method for Estimating the Tripartite Array Back-Azimuth Error Caused by the Far-Field Approximation





Case study: Mt. Meron event

- **IMS seismic array MMAI**
- **Infrasound array IMA**
- **Event near MMC3 on 25.08.2020**
- **Grid search location using seismic stations of MMAI**
- **Tripartite array <IMA1,IMA2,IMA2>**
- **Reference point IMA4**
- **R=1563 m (R=5.79r)**



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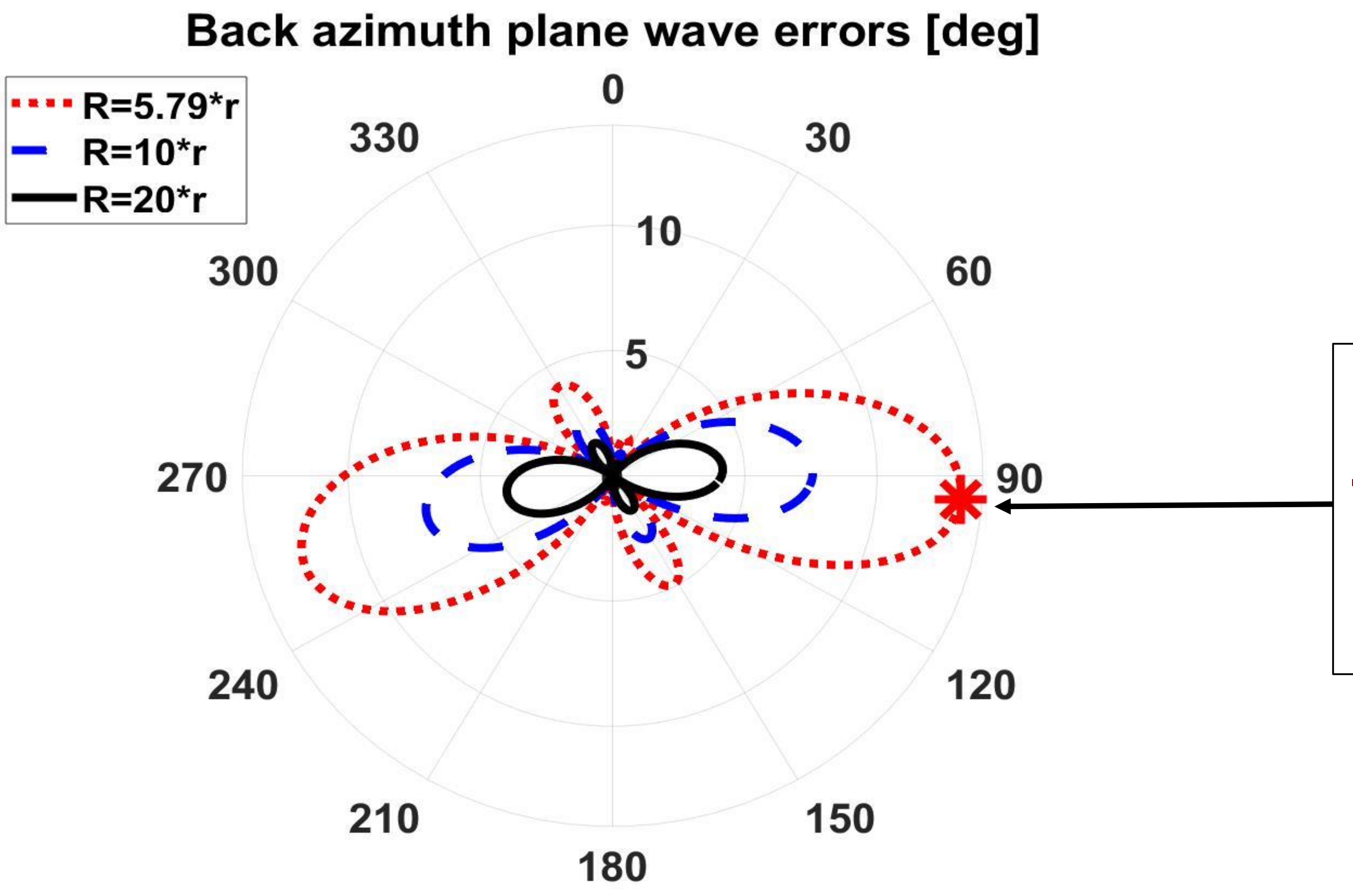
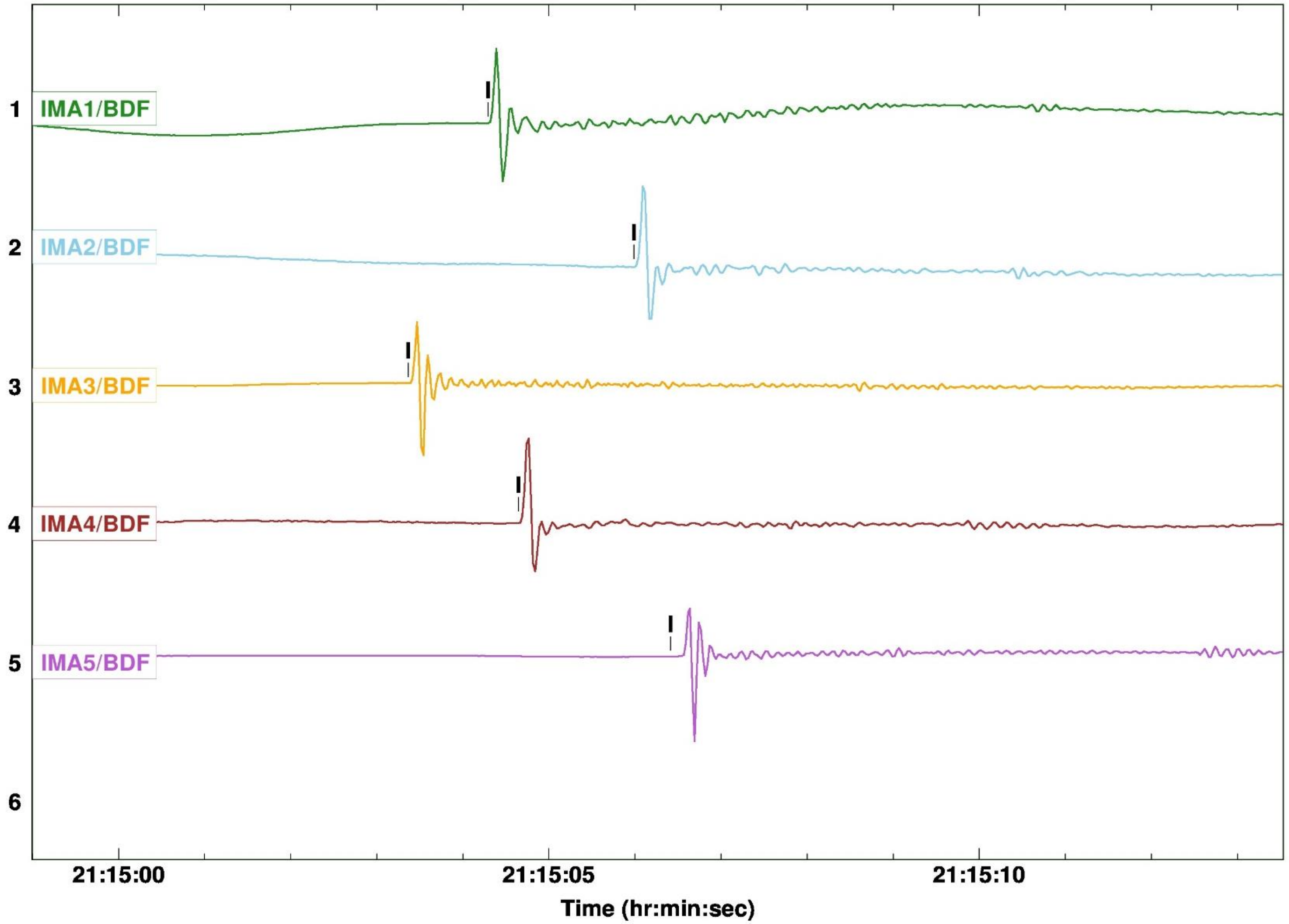


Back azimuth: 94.1°

Theoretical plane wave error: 13.8°

Mt. Meron event: (cont.)



Theoretical plane wave error: 13.8°

Estmated plane wave error: 13.2°

Summary

- We have analyzed the plane wave errors, i.e., the errors caused by the far field assumption.
- New computational formulas for the back azimuth plane wave error were developed.
- Back azimuth error are the result of the system geometry depending on:
  - Epicenter position.
  - Station locations.
  - Reference point location.

- The case study demonstrates that these errors are not theoretical issues only but can be significant in real measurements.
- We strongly recommend to take these errors into account for array aimed to measure low magnitude events during the passive seismic phase of the On-site Inspection.

Details: *Bregman Y., Ben-Horin Y., Method for estimating the tripartite array back azimuth error caused by the far field approximation, Seismological Research Letters, 2022, 93(6), pp. 3396–3403.*