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Nearfield Strong-motion Records of the 2023 M7.8 Kahramanmaraş Earthquake and Implications for High-frequency Radiation Mechanisms

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Summary

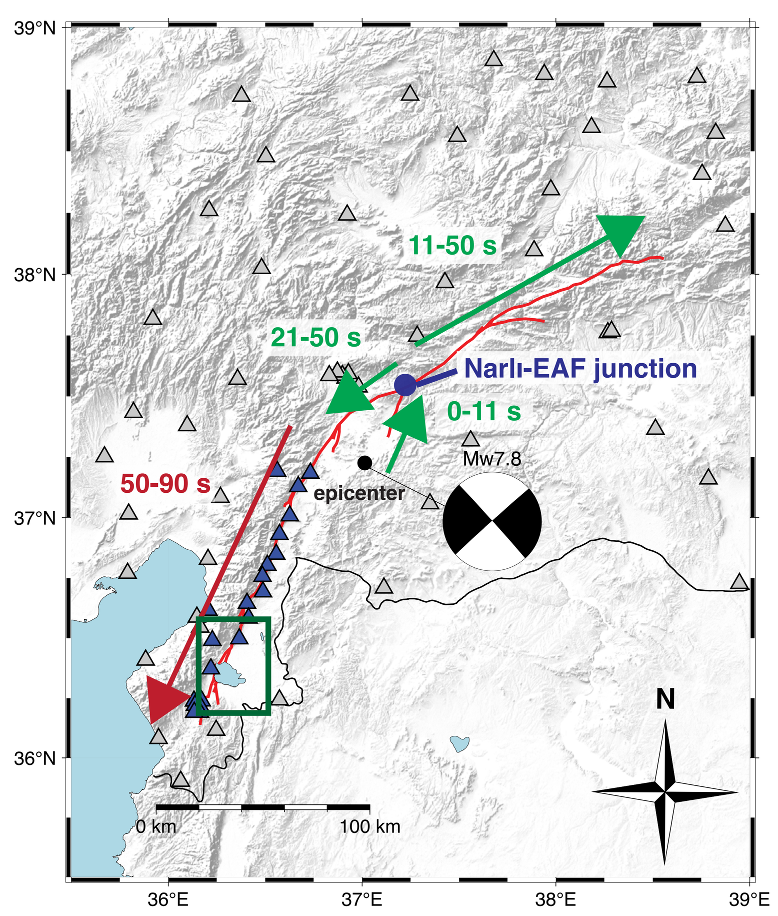
The Mw7.8 Kahramanmaraş earthquake was well recorded by the regional strong motion network operated by the Turkey Disaster and Emergency Management Authority (AFAD). Approximately 20 stations are located within 10 km of the East Anatolian Fault (EAF) surface rupture, south of the Narlı-EAF junction. These stations are distributed relatively evenly along the fault strike.

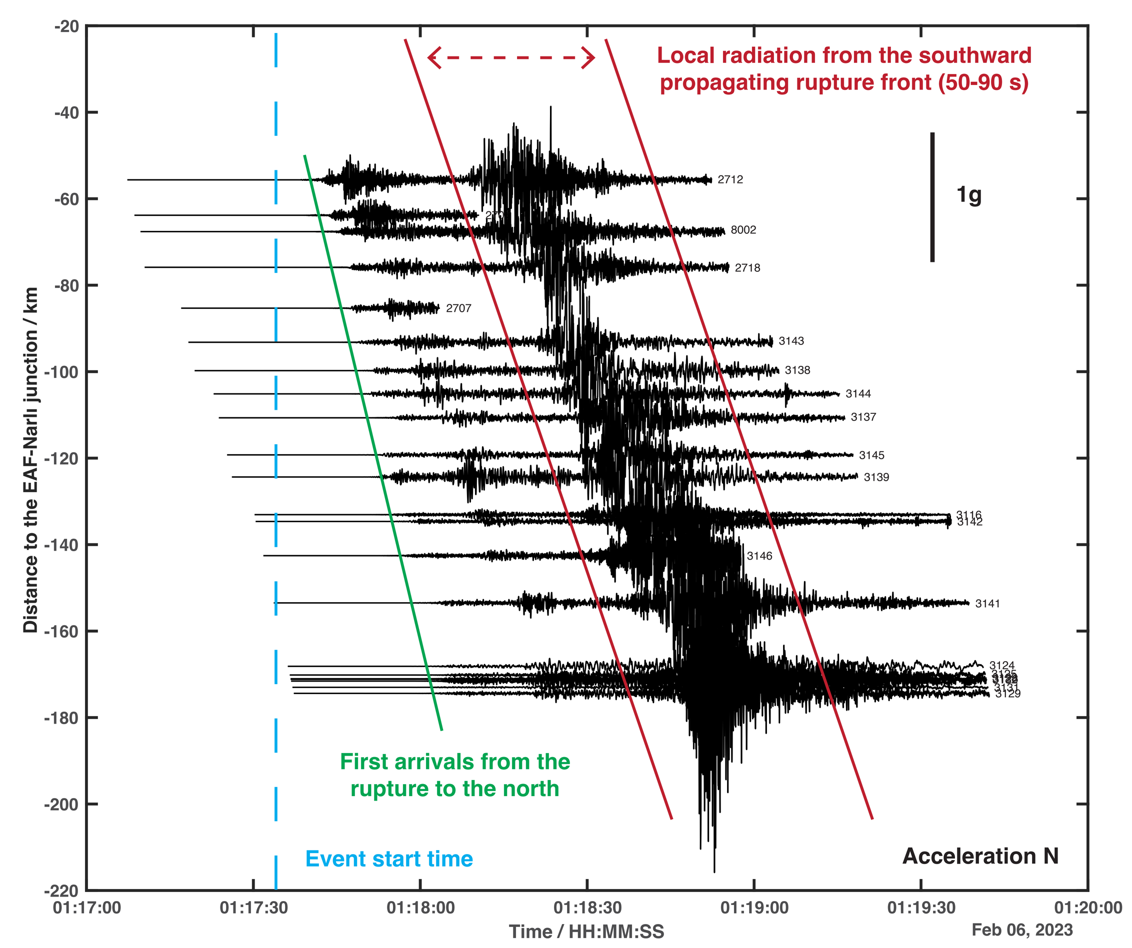
Due to their proximity, these records provide an unprecedented opportunity to directly investigate high-frequency radiation mechanisms at the rupture front—a crucial yet unresolved question—with minimal influence from path effects. We found most high-frequency energy arrived at these stations simultaneously with the low-frequency signals, suggesting similar source locations. However, seismic radiation higher than ~0.3 Hz displays distinct characteristics, including loss of radiation pattern and reduced correlation between horizontal components.

A state-of-the-art dynamic rupture model, constrained by surface rupture, aftershock location, coseismic deformation, low-frequency ground motion, regional stress field, and 3D velocity structure, could not reproduce these high-frequency ground motion characteristics. These inconsistencies imply a need to update current earthquake source representations for modeling high-frequency radiation. Our results provide quantitative constraints for future theoretical work aimed at distinguishing different high-frequency radiation hypotheses.

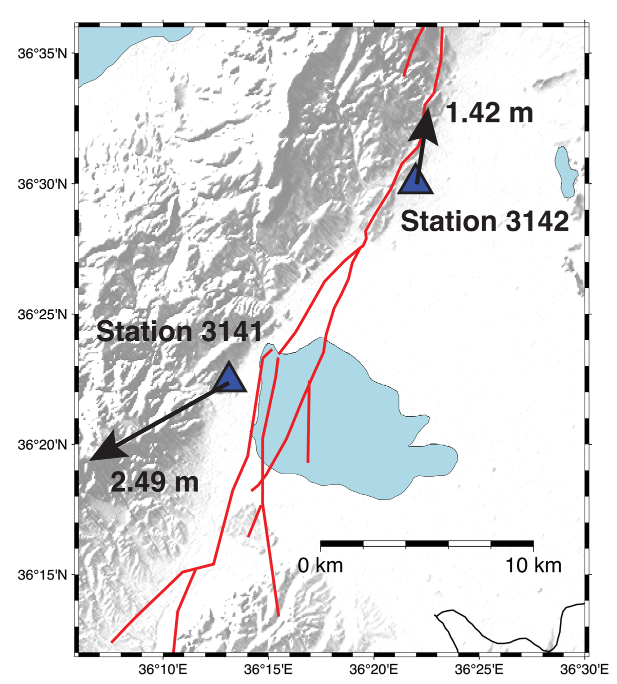
High-frequency radiation emitted from the rupture front

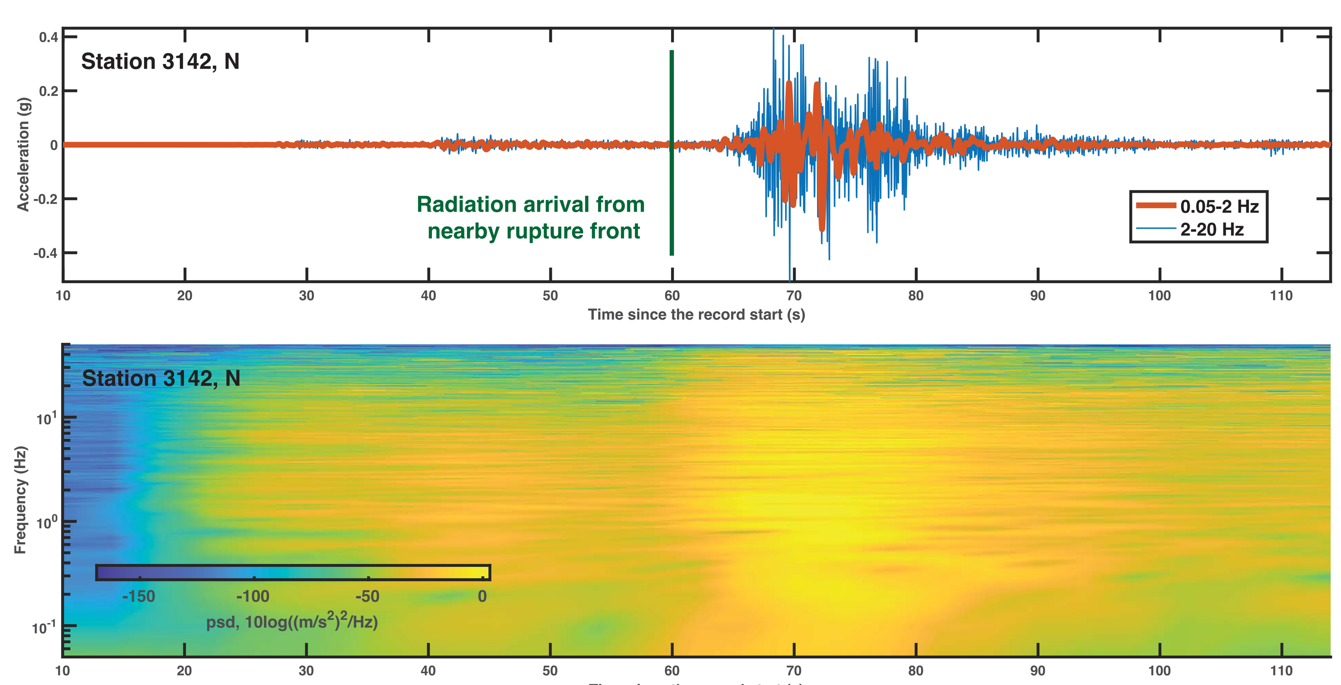
- Stations recorded rupture front radiation with minimal influence from path effects.



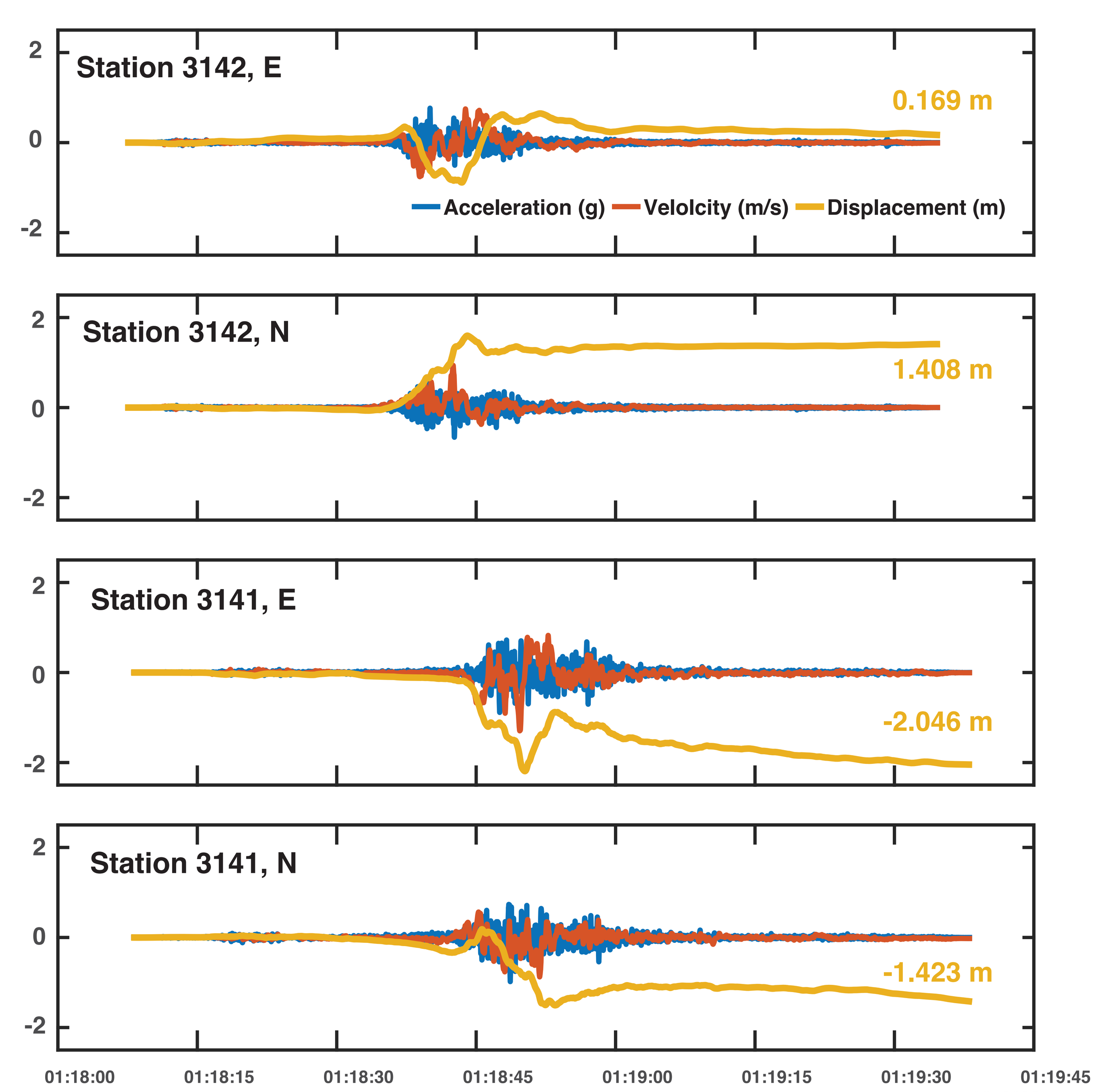


- High-frequency radiation concurrent with low-frequency radiation.

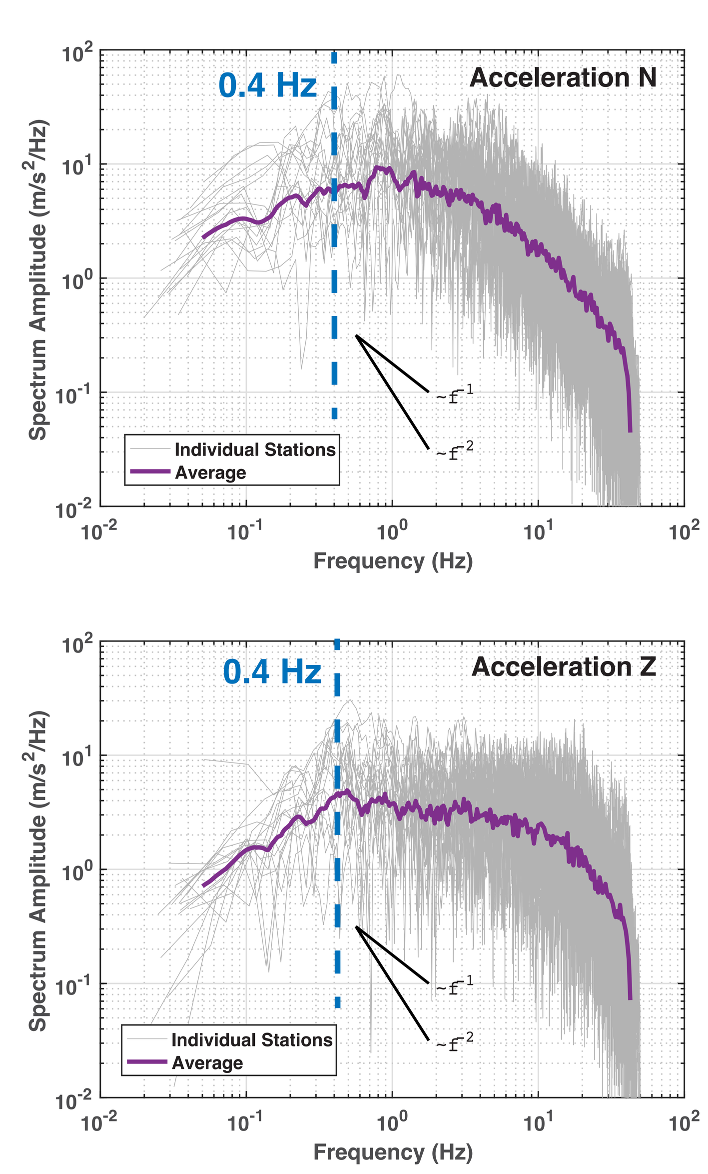




- High-frequency radiation concurrent with slip rise.



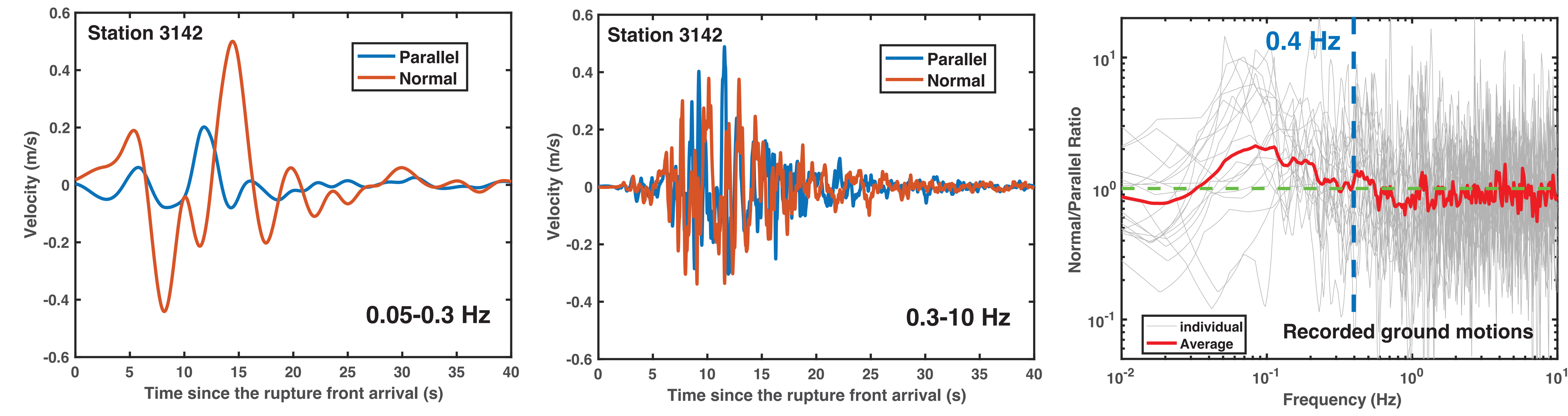
- Horizontal & vertical acceleration spectra



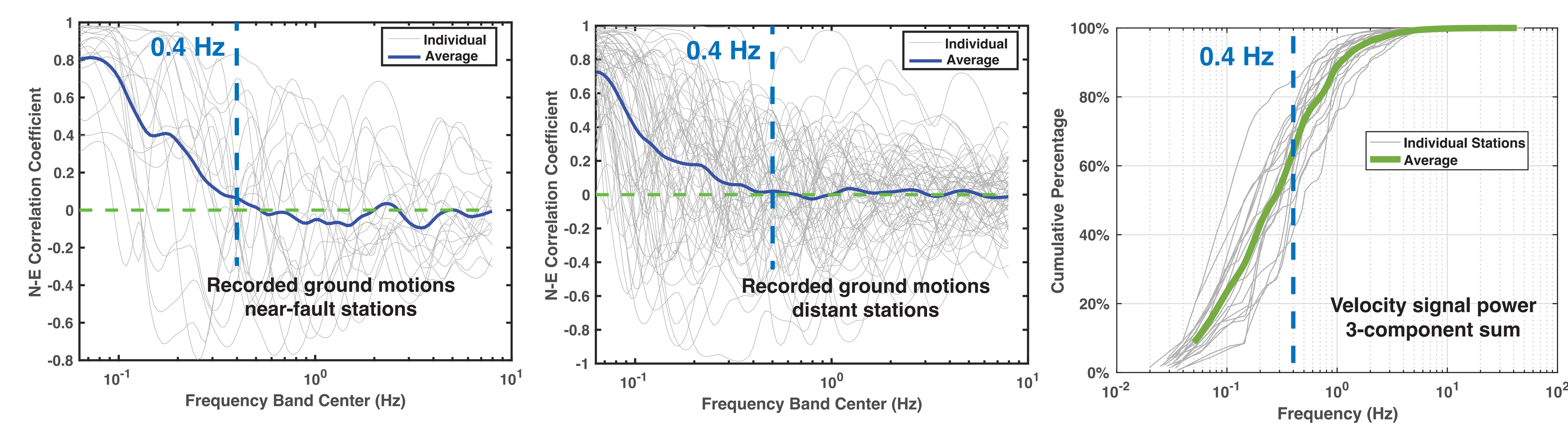
High-frequency characteristics that are challenging to explain

- Loss of horizontal polarity at high-frequencies

Also check Poster Group B 004, Ben-Zion et al.

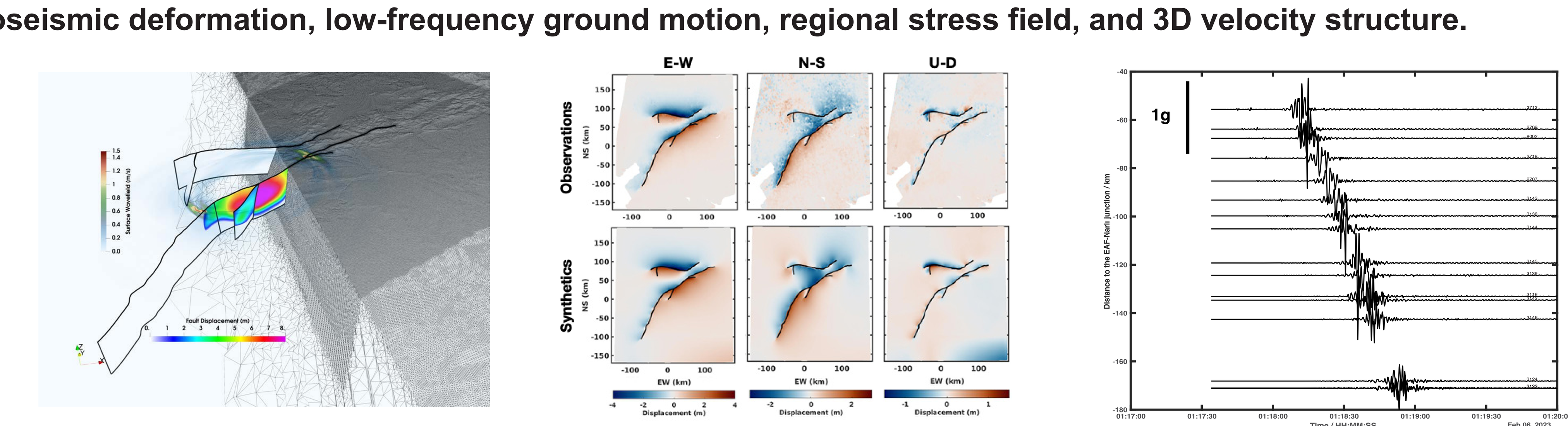


- Loss of between-component correlation at high-frequencies
- Energy partition across frequencies

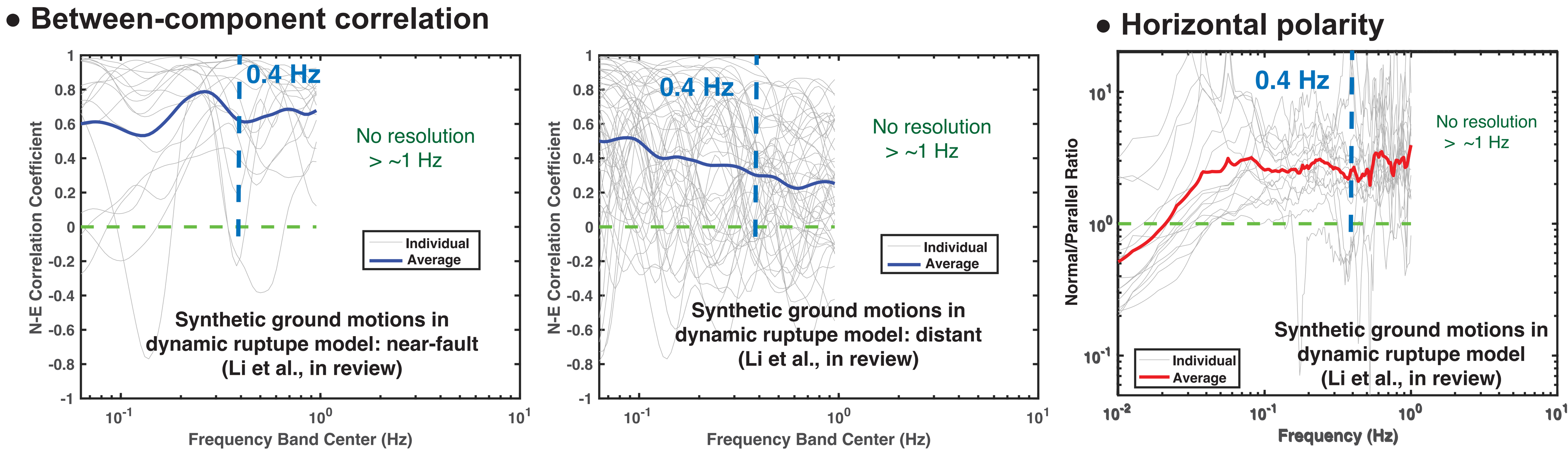


Dynamic rupture model constrained by "LF data" can't explain HF radiation

- (Li et al., in review) A SeisSol dynamic rupture model constrained by surface rupture, aftershock location, coseismic deformation, low-frequency ground motion, regional stress field, and 3D velocity structure.



- Between-component correlation
- Horizontal polarity



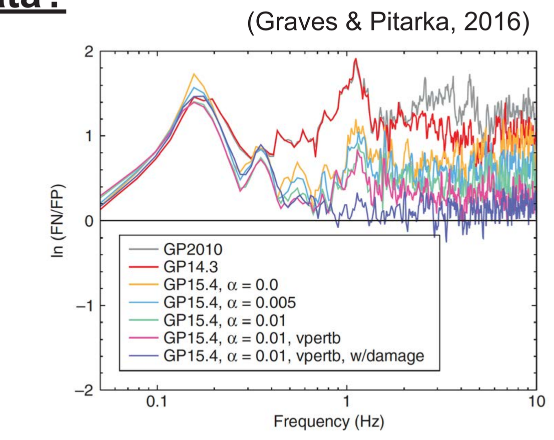
Implications for testing high-frequency radiation hypotheses

Novel insights from the M7.8 records of these close-to-fault stations:

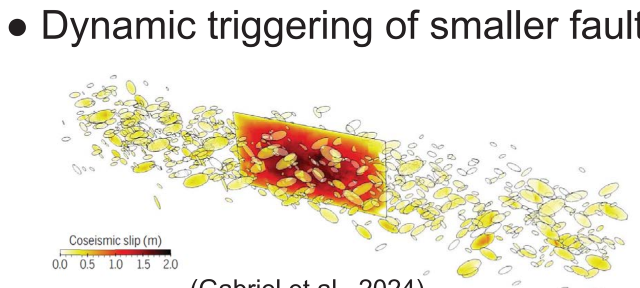
- Due to stations' great proximity to the fault (<10km), path-effects are minimal. The fact that most HF radiation is concurrent with LF radiation suggests that the uncharacterized HF radiation we observed is more likely generated concurrently at or near the rupture front as the slip occurs, rather than from scattering sources far away.
- We observed a loss of **horizontal polarity** and **between-horizontal-component correlation** at high frequencies, with transition frequency both around 0.3-0.5 Hz. Multiple mechanisms may explain these, more analysis is needed.
- Due to stations' proximity, we may directly estimate radiation energy with signal power. The uncharacterized HF radiation >~0.4Hz takes up ~40% of total radiation. The number can be used to quantitatively test HF hypotheses.

Which high-frequency radiation hypotheses are capable of explaining the M7.8 data?

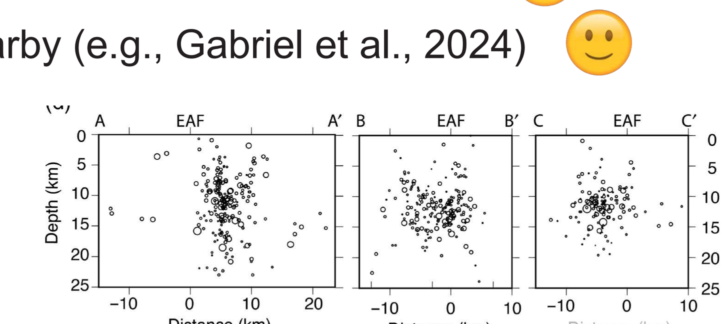
- Heterogenous slip/rupture speed (e.g., Madariaga, 1977; Hanks, 1979) 🙁
- Small-scale fault roughness (e.g., Dunham et al., 2011; Shi & Day, 2013) 🤔
- Fault-zone reflection/trapped/scattering waves (e.g., Graves & Pitarka, 2016) 🙂
- Coseismic damage (e.g., Ben-Zion & Ampuero, 2009; Okubo et al., 2019) 🙂
- Medium scattering (e.g., Imperatori & Mai, 2013; Takemura et al., 2015) 🙁
- Impact and collision of fault zone structures (e.g., Tsai et al., 2021) 🙂
- Dynamic triggering of smaller faults nearby (e.g., Gabriel et al., 2024) 🙂

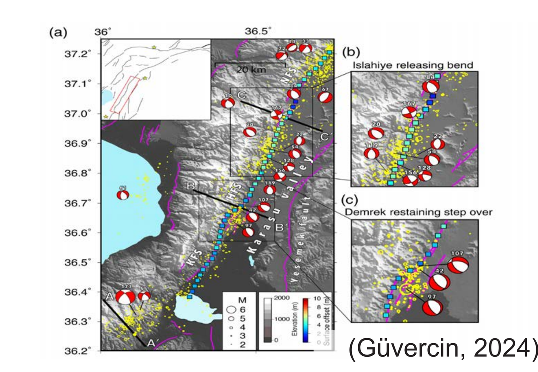


(Graves & Pitarka, 2016)



(Gabriel et al., 2024)





(Güvercin, 2024)

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