Report of Transnational Access Projects

(Note: the information here will be publicly disclosed in the Geo-INQUIRE website, do not include sensitive information)

Project ID: *TA2-542-1*

Principal investigator: *Baran Güryuva, ORCID: 0000-0003-3160-7860*

Project team (if applicable): -

Project title: *EMME24 Refinement and Investigation of Regional Aspects*

Project acronym: *EMME24-RIRA*

Hosting installation: *EF-PSHA – Probabilistic Seismic Hazard Analysis*

Hosting team: *Dr. Laurentiu Danciu in SED, ETH Zürich*

Period of access: *23-27 February 2026, 20-24 July 2026*

Report of activities:

This report summarizes the activities conducted during the collaborative research project under Geo-Inquire (TA2-542-1) in Zurich, hosted by Dr. Laurentiu Danciu. The primary objective of this project is to evaluate the performance of the backbone model developed for the EMME24 update within the target region.

The EMME24 framework is designed to provide a consistent foundation for seismic hazard assessment in regions where limited strong-motion data restrict the development of fully regionalized ground-motion models (GMMs). Despite these data limitations, the existence of several regional and international databases, seismic networks, and event-specific studies allows for a systematic performance evaluation of the newly developed backbone model.

The research activities under Geo-Inquire are structured into four main components:

- Compilation and harmonization of the available regional strong-motion data.
- Residual analyses, performance testing, and assessment of overall data availability.
- Identification and investigation of regions exhibiting systematic ground-motion deviations.
- Development of regionalization corrections for zones demonstrating significant deviations and sufficient data coverage.

While the primary scientific objectives are focused on regionalization and deviation analysis, the compilation and harmonization of the database represent the most time-intensive stages of the project.

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Database Compilation and Harmonization

To construct a robust earthquake database for the target regions, event information was initially compiled through the International Seismological Centre (ISC) network. For criteria earthquakes (magnitude > 5), data from other seismological agencies were also cross-referenced. Geophysical parameters, including origin time, latitude, longitude, depth, fault geometry (strike, dip, rake), rupture dimensions, and standardized moment magnitude scales, were systematically collected.

Because Turkey and Iran already possess unified metadata and Intensity Measure (IM) flatfiles, they were handled differently. Turkey was excluded from this specific data-gathering phase, as it falls largely outside the scope of the EMME26 project borders and is included in the ESHM framework. Conversely, the existing comprehensive flatfile for Iran was directly integrated into the project database.

For the remaining regions—specifically the Middle East, Afghanistan, and surrounding areas—data gathering was conducted via the FDSN network due to a lack of accessible national agency data. Continuous data networks active from the 1990s to the present were evaluated. Out of 23 candidate stations, only four networks possessed usable and accessible data for the region:

- **Jordan:** JS Network
- **Afghanistan:** 4C (2017) Network
- **Georgia:** GO Network
- **Armenia:** A2 Network

It should be noted that the temporal coverage for these networks is highly constrained, with the longest active continuous recording period spanning only two years across all four networks.

Station Metadata and Waveform Processing

A significant limitation encountered during compilation was the absence of measured time-averaged shear-wave velocity in the top 30 meters (V_{S30}) for the station sites. To resolve this, proxy values were extracted from the USGS Topographic Slope-Based V_{S30} Map. While high variability is inherent in proxy-based V_{S30} estimates, this uncertainty is anticipated to be absorbed and corrected by the site-to-site residuals during the regression phase.

For waveform downloading, a geographic radius of 300 km from the ISC-located epicenters was applied to the available stations. Continuous waveform data were downloaded using a standardized time window: two minutes prior to and four minutes following the earthquake origin time.

The downloaded continuous records were subsequently subjected to the automated processing scheme outlined by Sandıkkaya et al. (2024). This automated protocol was utilized to sort and separate high-quality records from poor-quality data. The retained high-quality records were automatically trimmed and processed. Finally, Intensity Measure Types (IMTs), specifically Pseudo-Spectral Acceleration (PSA) at 5% damping for a set of predefined periods, were calculated using the RCTC software. To ensure maximum coverage, this compiled FDSN dataset was further enriched with data from existing projects, including the ESM, RESORCE, and NGA-West databases (Figure 1).

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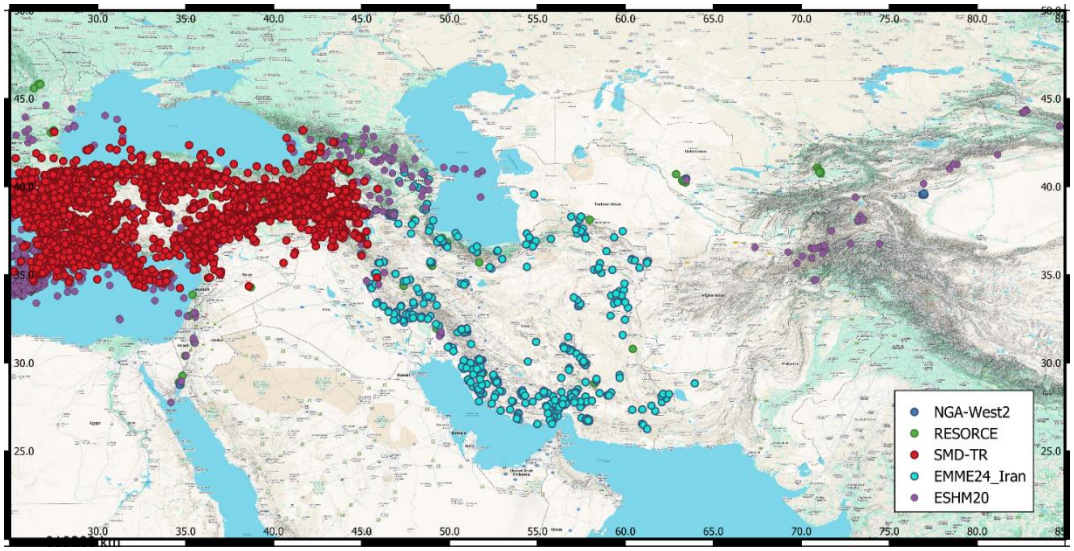

Figure 1: Availability of Strong-motion data in various regional studies

Data Distribution and Regional Constraints

Extensive investigations of the compiled records were conducted to evaluate magnitude and distance distributions. While the Iranian flatfile demonstrates a robust and extensive data distribution, the newly compiled regions exhibit significant scatter limitations (Figure 2). However, this is not considered a critical deficiency; in shallow active crustal regions where tectonic constraints preclude extreme-magnitude events, obtaining certainty for such high magnitudes is both unachievable and unnecessary.

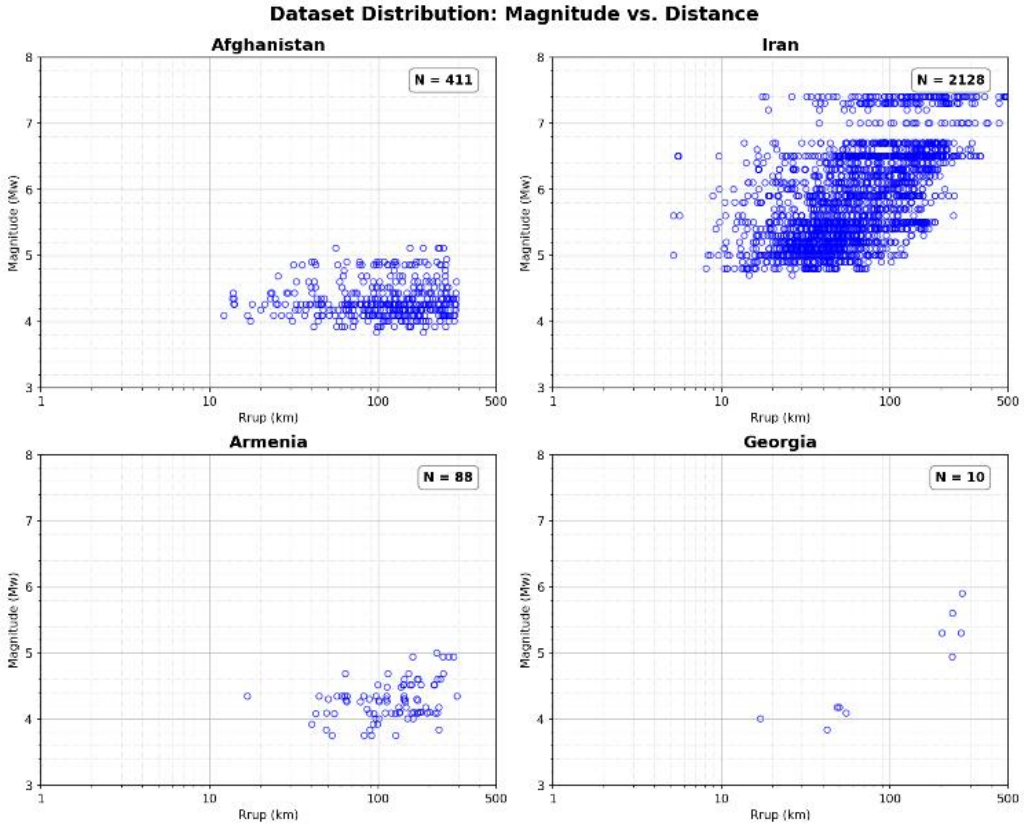

Figure 2: Magnitude-Distance Scatter for the selected regions

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Due to data sparsity and shared tectonic characteristics, the records from the Armenia and Georgia networks were merged into a single "Caucasus" dataset. Consequently, sufficient data volumes were achieved for Iran, Afghanistan, and the Caucasus to compute regional ergodic corrections (similar to the methodology applied in NGA-West). Conversely, the dataset size remains insufficient to support fully non-ergodic, station-specific methodologies. (Regions such as Iraq and Pakistan yielded no usable data, reaffirming the necessity of the EMME24 project framework).

Residual Analysis and Model Correction

To evaluate performance, identical scenarios from the database were evaluated using the central EMME24 backbone model (BBEMME3), representing the median prediction. Total residuals between the observed IMTs and the median predicted values were calculated.

These total residuals were subsequently partitioned into between-event (δB_e), site-to-site ($\delta S2S_s$), and within-event (δW_{es}) residuals utilizing linear mixed-effects regression (lmer).

The partitioned residuals were analyzed to identify systematic biases. Between-event residuals were investigated for magnitude-dependent scaling. Within-event residuals were investigated for distance-dependent attenuation effects. Because regional discrepancies in distance scaling are primarily driven by anelastic attenuation, this investigation was strictly focused on rupture distances greater than 80 km. Results for Iran data over PGA, and the selected periods, T0.05-T10 are detailed in the appendix.

Linear regression equations were formulated based on these magnitude and distance dependent residuals to derive fixed, regional adjustment coefficients. To ensure these regional adjustments do not introduce unphysical discontinuities into the overall structural shape of the response spectra, the resulting regression coefficients were smoothed across the entire evaluated period range (Figure 3).

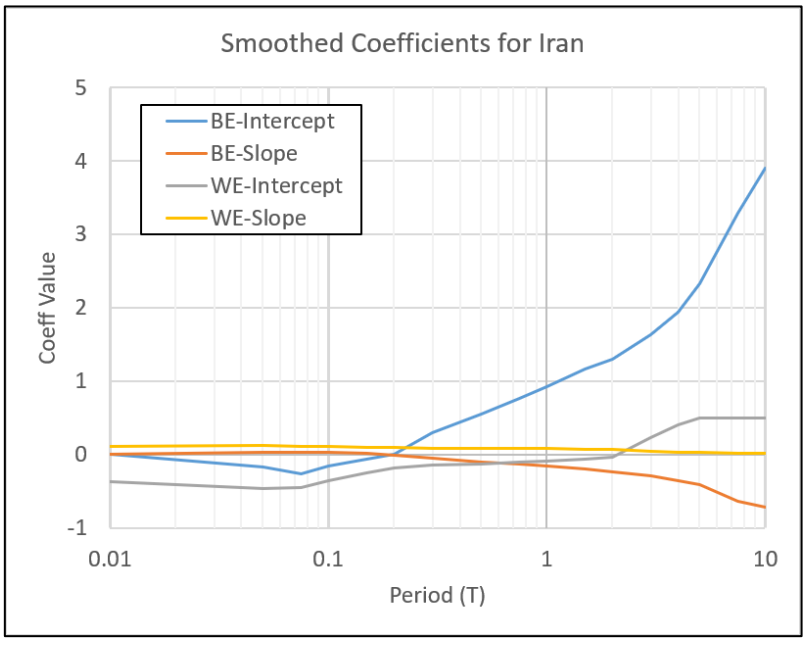

Figure 3: Smoothed Coefficients for Iran

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The Investigated differences are quantified in a way to add for fixed, magnitude based and distance-based manner, so for regional studies, a fix for the region can be used with the formula:

$$\ln(y_{region,corrected}) = \ln(y_{BBEMME3}) + be_{fixed} + be_{mag} * M_W + we_{fixed} + we_{dist} * \ln(R_{rup} - 80)$$

T	be_{fixed}	be_{mag}	we_{fixed}	we_{dist}	T	be_{fixed}	be_{mag}	we_{fixed}	we_{dist}
PGA	0.00093	-0.00017	-0.36542	0.10467	1	0.92123	-0.16017	-0.09078	0.08292
0.05	-0.17463	0.03188	-0.46828	0.11961	1.5	1.16100	-0.20135	-0.06780	0.07001
0.075	-0.26682	0.02923	-0.45130	0.11172	2	1.30130	-0.23757	-0.03822	0.06614
0.1	-0.16066	0.02640	-0.35713	0.10836	3	1.63120	-0.29779	0.23173	0.04181
0.2	-0.00338	-0.01000	-0.18466	0.08961	4	1.93610	-0.35346	0.40972	0.03229
0.3	0.30104	-0.05496	-0.14927	0.08513	5	2.33130	-0.41320	0.49254	0.02336
0.5	0.55627	-0.10155	-0.13227	0.08345	7.5	3.29137	-0.63249	0.49254	0.01570
0.75	0.75799	-0.13537	-0.10870	0.07883	10	3.90880	-0.71359	0.49254	0.01495

Project outcomes:

At the end of this project, available data in the Middle-east region has been compiled and is now in processed form for future engineering work.

The Flatfile for the Investigated regions include event information, rupture information, distance metrics, and IMT values for PGA, T=0.05-10 seconds. The EMME26 backbone model is available in openquake. The data about Iran and EMME26 studies are to be used in my doctoral studies as a major part of the regionalization process.

Note: Data, products, software and publications resulting from TA activities must be publicly accessible under a CC-BY 4.0, GPLv3 or equivalent open license. No embargos beyond June 2026 are allowed. They must cite Geo-INQUIRE as the source of funding. Minimal citation: "*Geo-INQUIRE is funded by the European Union (GA 101058518)*".

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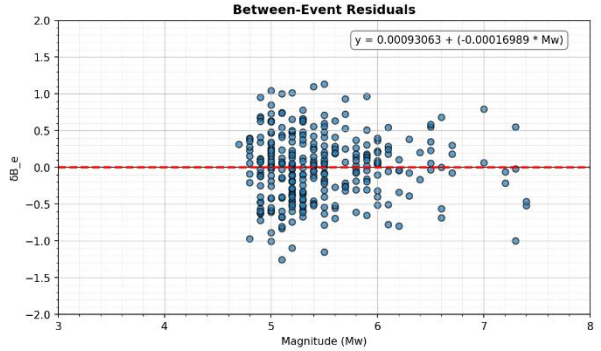
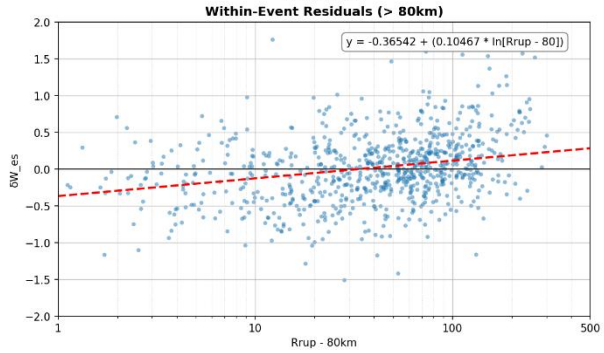
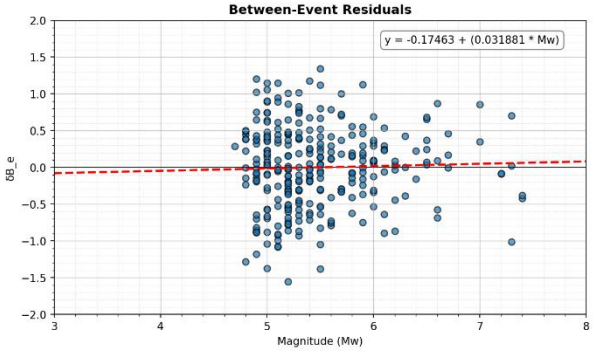
Appendix:

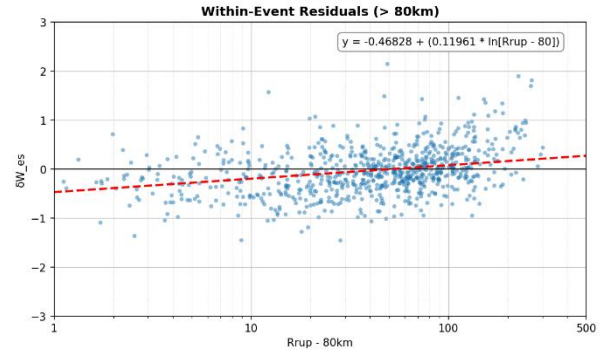
Iran - Period: PGA Regression





Iran - Period: T0.05 Regression





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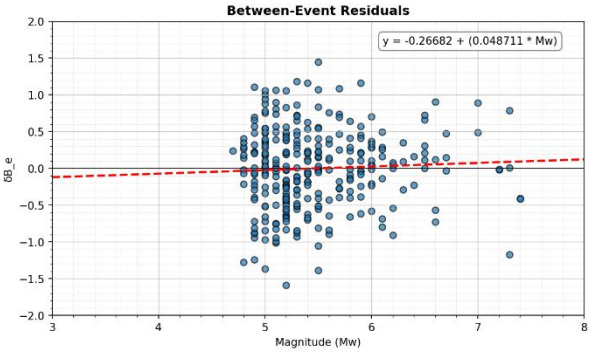
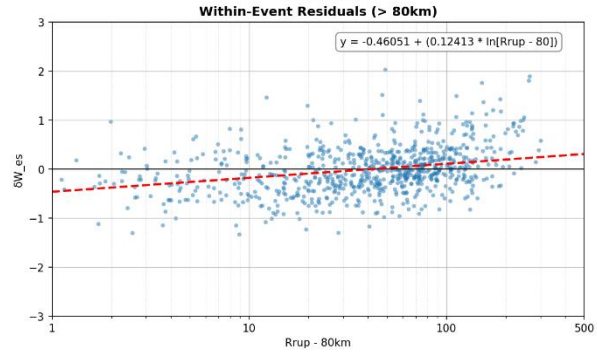
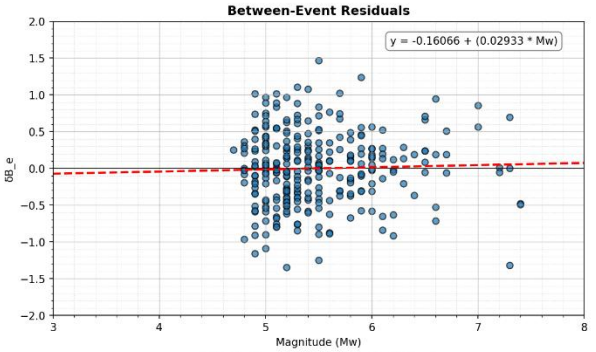
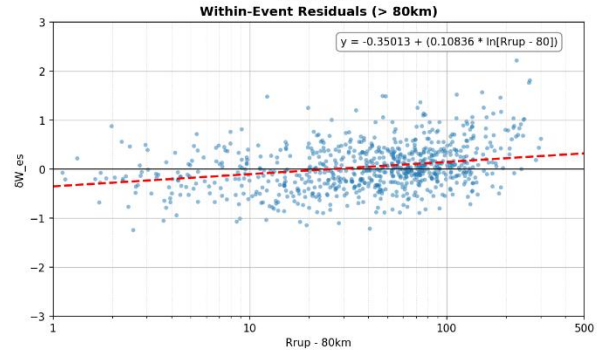
Iran - Period: T0.075 Regression



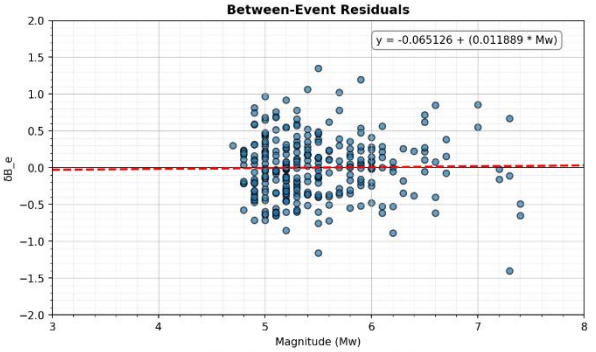


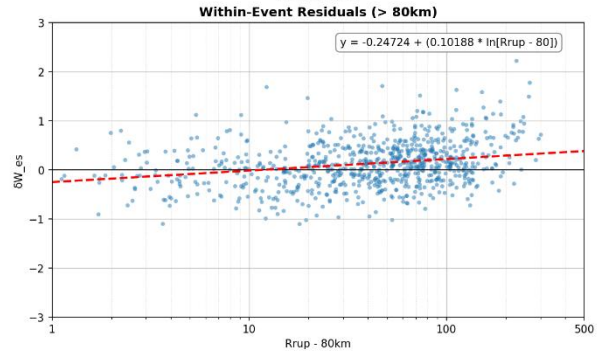
Iran - Period: T0.1 Regression



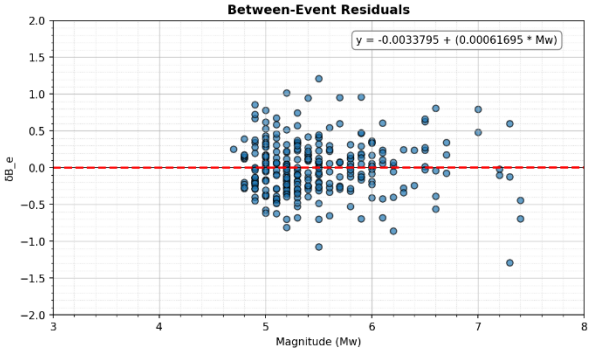


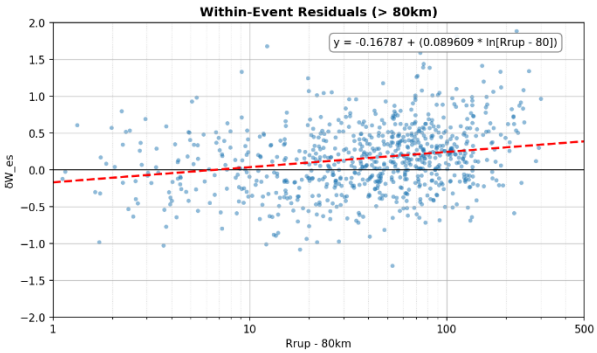
Iran - Period: T0.15 Regression





Iran - Period: T0.2 Regression





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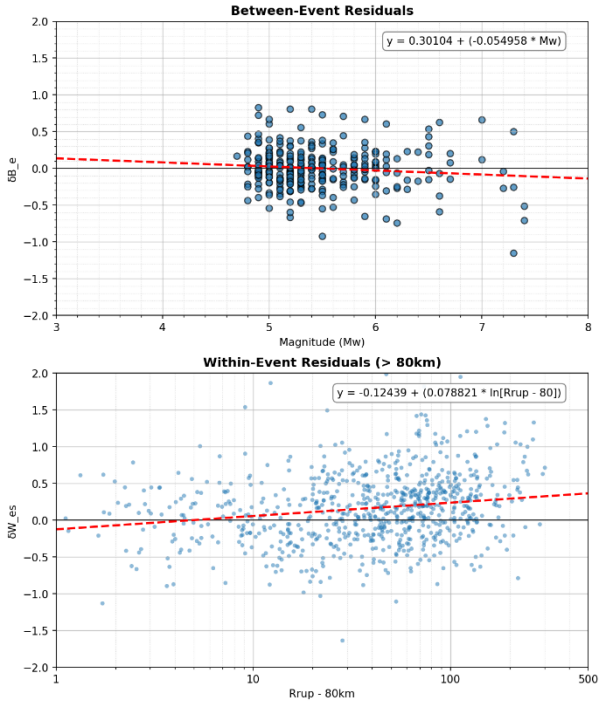
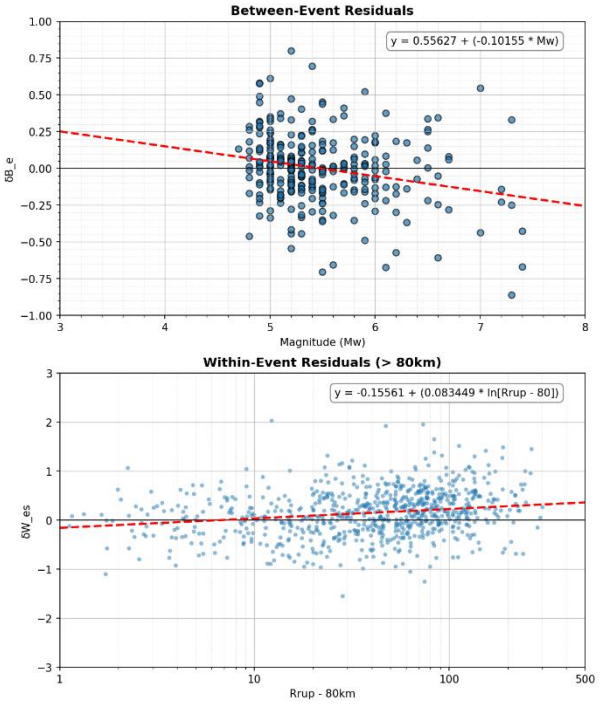
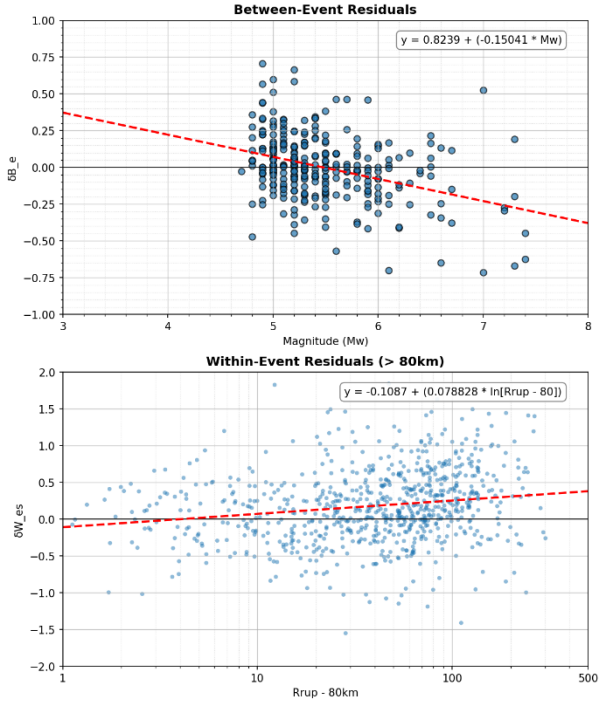
Iran - Period: T0.3 Regression



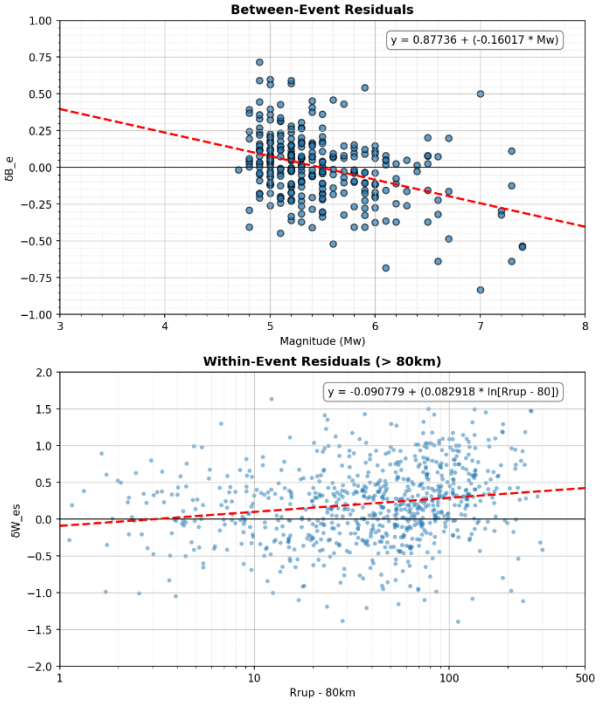
Iran - Period: T0.5 Regression



Iran - Period: T0.75 Regression



Iran - Period: T1.0 Regression



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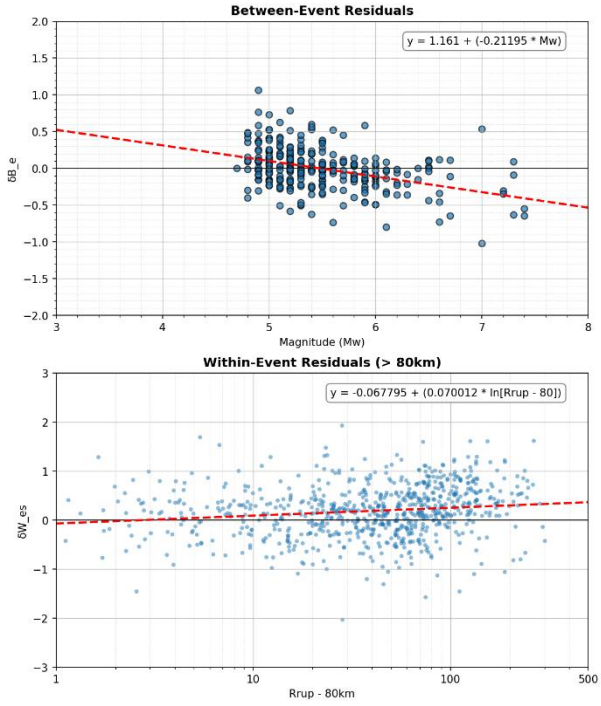
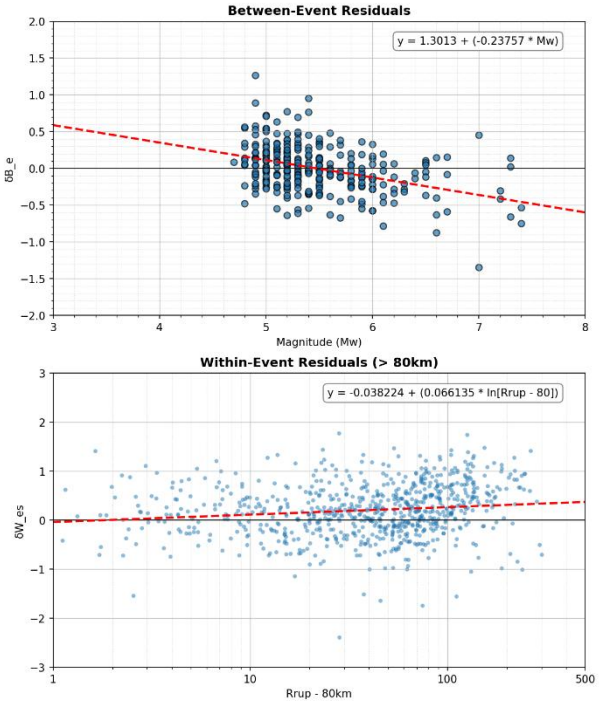
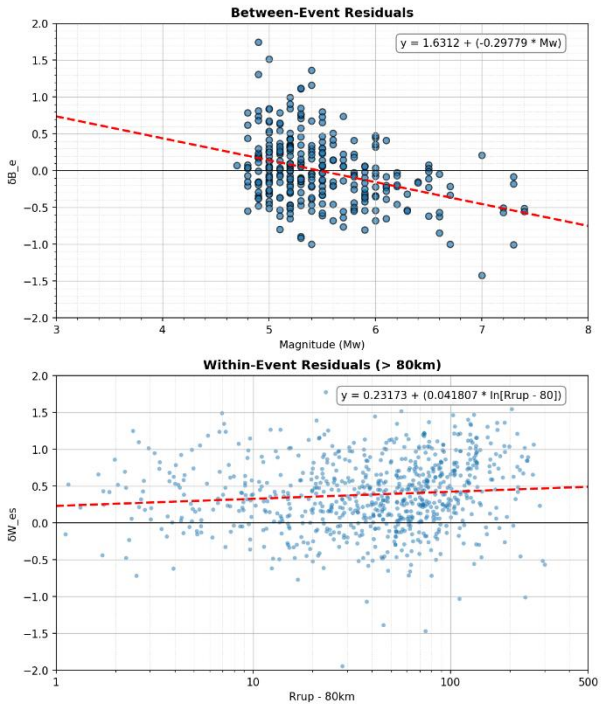
Iran - Period: T1.5 Regression



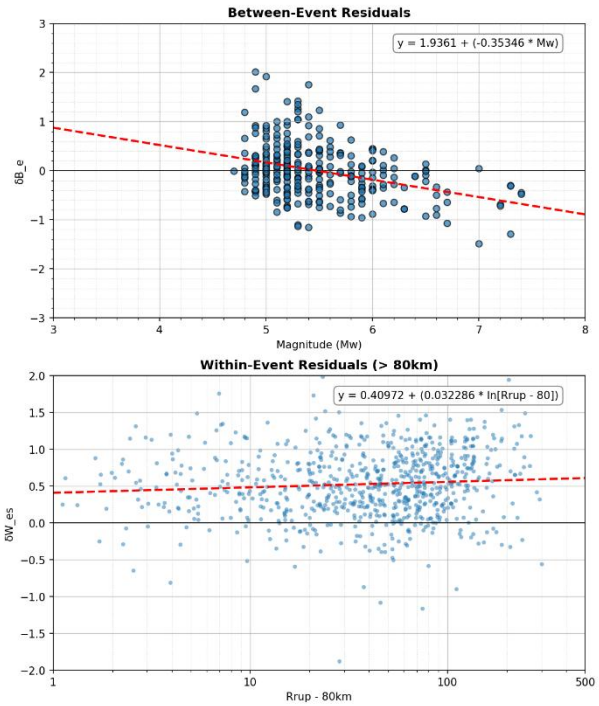
Iran - Period: T2.0 Regression



Iran - Period: T3.0 Regression



Iran - Period: T4.0 Regression



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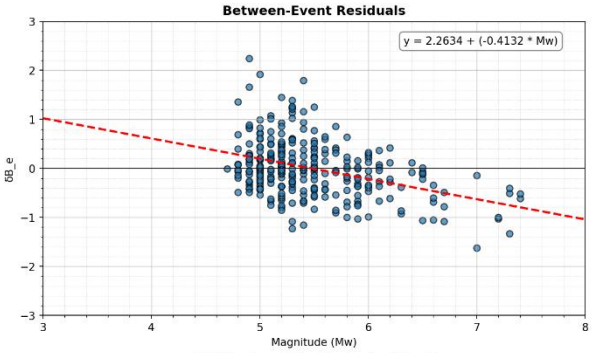
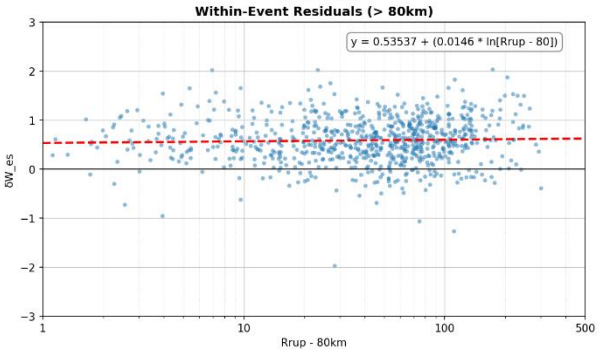
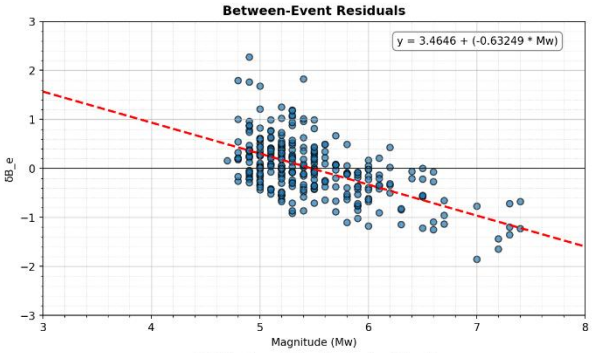
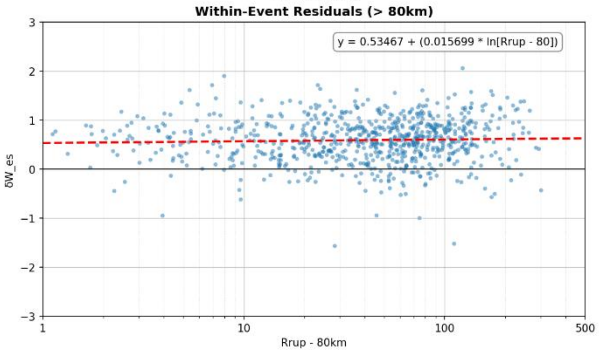
Iran - Period: T5.0 Regression



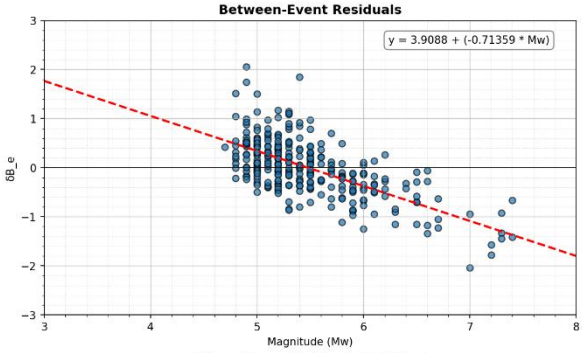


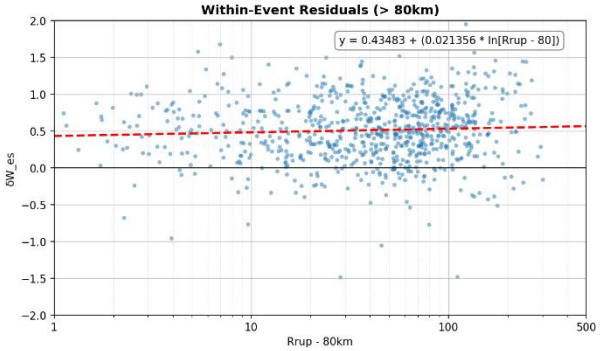
Iran - Period: T7.5 Regression





Iran - Period: T10 Regression





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