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Temporal Evolution of Microseismicity in Response to Reservoir Operation at the Enguri Dam (Georgia)

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ABSTRACT

In this study, we analyze the temporal evolution of microseismicity near the Enguri Dam (Georgia) using over four years of data from a local seismic network installed under the DAMAST project. A detailed completeness analysis identifies a conservative threshold of Mc = 0.6 within 17 km of the dam, enabling robust estimation of Gutenberg–Richter parameters. Elevated b-values in the local catalog—compared to national Mw-based data—suggest a significant reservoir-induced component. Extending the analysis to a 30 km radius, we find that the completeness threshold increases to Mc = 1.0; however, the b-value remains high (≥ 1) when estimated using the Maximum Likelihood method. This spatial consistency in elevated b-values indicates that reservoir operations influence seismicity up to at least 30 km from the dam. Seismicity correlates with water level changes, especially during filling and drawdown phases, while meteorological variables show no consistent relationship. Our findings highlight the influence of reservoir operations on microseismic activity and underscore the value of integrated hydrological and seismological monitoring in dam regions.

Key words: *microseismicity, Inguri reservoir, seismic catalog analysis, b-parameter assessment.*

Introduction

In this study, we analyze over four years of continuous seismic monitoring around the Enguri Hydropower Plant (HPP) using the DAMAST seismic network. The Enguri arch dam, standing 271.5 m high, is among the tallest dams in the world. Its reservoir, Jvari-approximately 30 km long and reaching depths of up to 226 m-is located in the Samegrelo region of Georgia. The underground powerhouse is situated in the Gali District of the Abkhazia region and is connected to the reservoir via a 15 km long headrace tunnel. The entire Enguri HPP system represents one of the most complex and strategically important hydropower infrastructures in the South Caucasus. Despite the political conflict, the plant has continued to operate as a shared energy facility, supplying electricity to both Abkhazia and other region of Georgia through ongoing technical cooperation and joint operation agreements. This region, approximately 50 km east of the Black Sea in the west part of Georgia, lies within an active seismotectonic zone associated with the southern margin of the Greater Caucasus. The seismotectonic setting of the area has been described in detail in our previous publications [1-2]. Accordingly, we omit a detailed discussion here and briefly note that the Enguri high dam is located within an active tectonic zone along the southern margin of the Greater Caucasus. The associated seismogenic source is defined based on national earthquake catalog data (Mw ≥ 3.0), and its Gutenberg–Richter (GR) parameters a-value and b-value [3] have been estimated using various statistical methods. Importantly, these parameters were derived from cataloged tectonic earthquakes only; reservoir-induced events were not included in the analysis. The estimated values are presented in Table 1.

With the improved detection capabilities of the DAMAST seismic network, it is now possible to estimate Gutenberg–Richter parameters, based on a more complete catalog that includes low-magnitude events (Mw < 3.0). This allows, for the first time, a direct comparison between the statistical properties of microseismicity and those derived from the national catalog, which only includes moderate to large tectonic events. Such a comparison provides a basis to investigate whether the microearthquake population reflects the same seismotectonic regime as larger tectonic earthquakes, or whether it reveals distinct characteristics potentially linked to reservoir-induced processes. The outcome of this comparison has important implications for understanding the nature of small-magnitude seismicity near large dams and its relation to regional tectonic stress fields. In this paper, we focus in particular on the b-value of the Gutenberg-Richter relation. The b-value of the Gutenberg-Richter law not only reflects the relative proportion of small to large earthquakes but also serves as an indicator of the mechanical state of the crust. Higher b-values are generally associated with heterogeneous, fractured, and fluid-influenced rock masses, often implying the presence of stress perturbations, increased pore pressure, or weaker fault structures. In contrast, lower b-values typically indicate a more homogeneous and competent lithology subjected to higher differential stress. Therefore, the elevated b-values observed near the Enguri Dam may suggest that the surrounding rock volume is extensively fractured and potentially weakened by repeated hydrological loading, making it more susceptible to microseismic activity triggered by minor stress changes due to reservoir operation.

Seismic Networks and Data

To capture low-magnitude seismicity in the vicinity of the Enguri Dam, a dedicated local seismic network comprising ten stations was established under the DAMAST project. (Fig. 1). The network consists of both surface (KETI, BRID, GULB equipped with MBB-2 sensors and HPP, OKM, GAL equipped with 4.5 Hz Geophone PE-6/B**)** and borehole (KIT1, BUFF, NIKA, DOG equipped with Trillium Compact Posthole 20s sensors) installations.

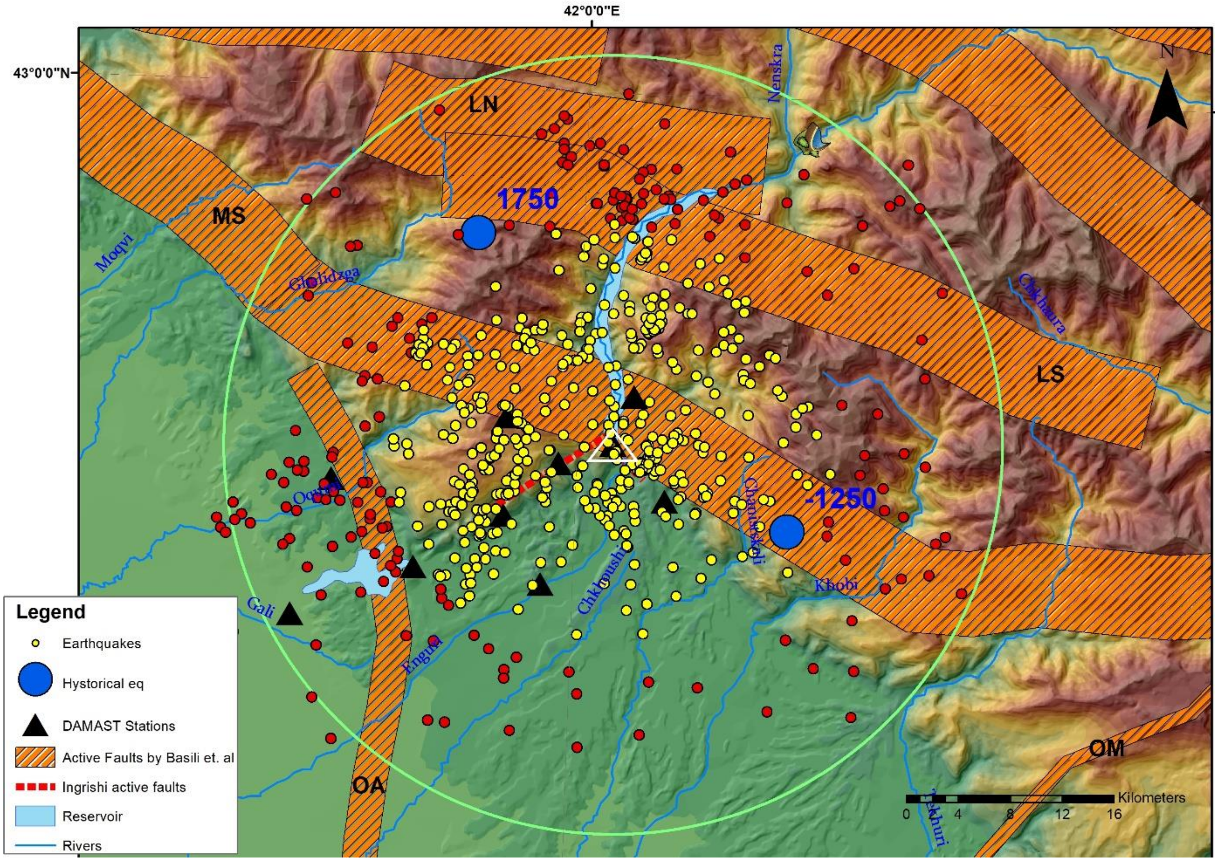


Fig. 1. Damast seismic network, seismicity and active fault structures in the Enguri Dam region. Yellow circles indicate microearthquakes recorded between 2020 and 2024 within 17 km radius.

Fig. 2 presented a normalized comparison plot showing the amplitude response of all three sensor types. A -3 dB reference line is included to indicate the effective bandwidth for each sensor. The comparison confirms that the Trillium 20s sensor provides the broadest usable frequency range, followed by the MBB-2, with the 4.5 Hz geophone effective in the high-frequency band only.

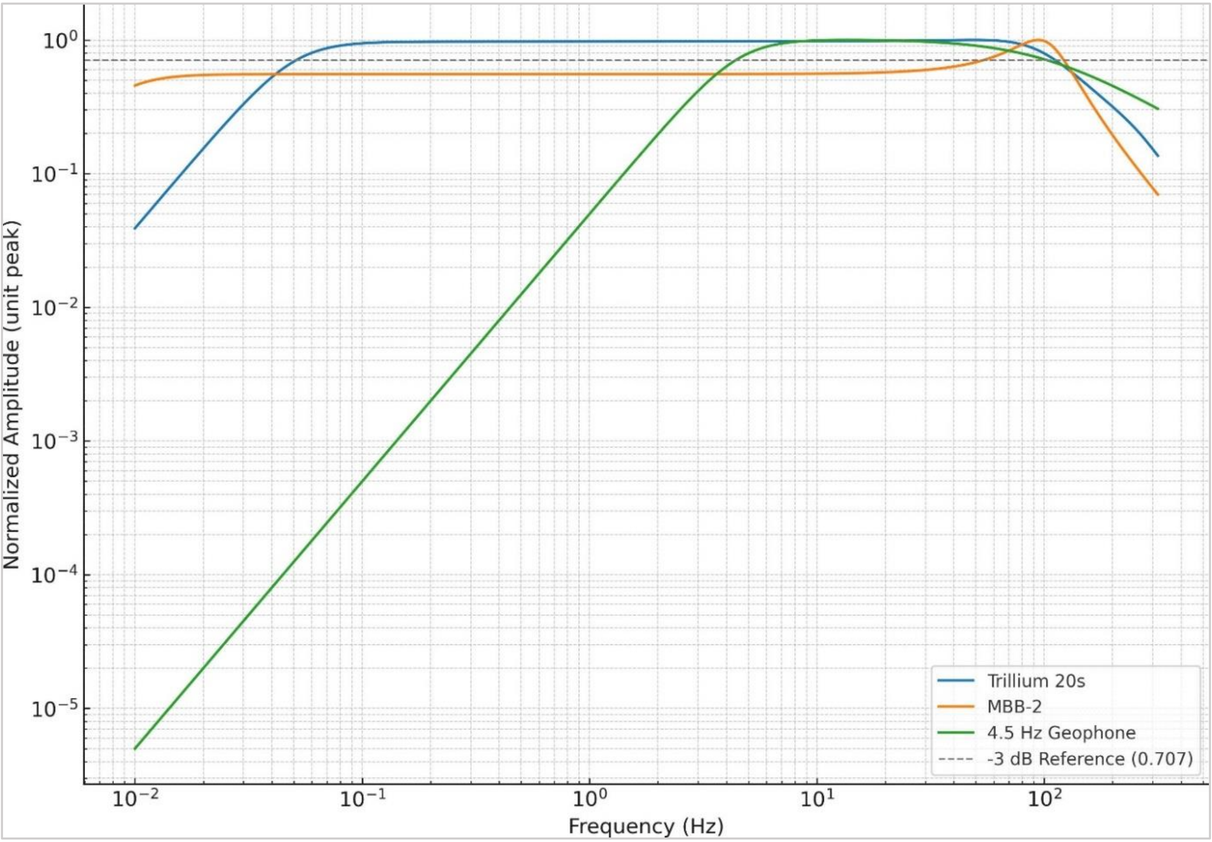


Fig. 2. Normalized Frequency Response of Trillium 20s, MBB-2, and 4.5 Hz Geophone Sensors.

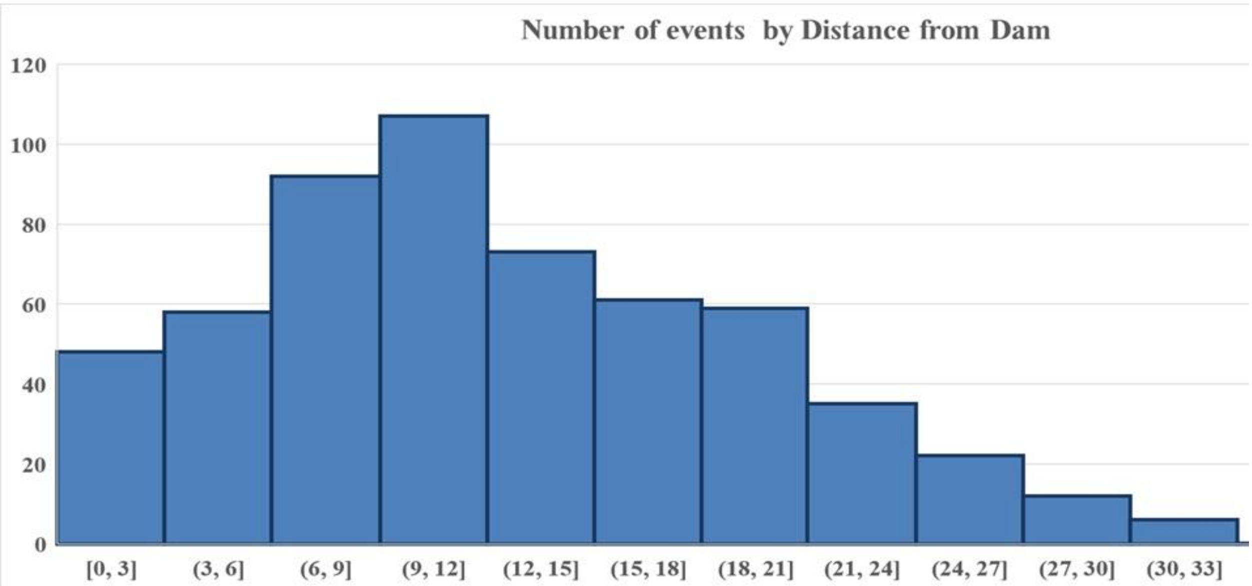
Background seismic noise conditions were evaluated through vertical-component power spectral density (PPSD) analysis for each station, using the ObsPy package. Median acceleration-referenced spectra were computed and compared against Peterson's New High and Low Noise Models (NHNM and NLNM; [4]) to characterize site-specific noise levels The borehole installations (KIT1, BUFF, NIKA, DOG) and the remote station GULB consistently demonstrated low ambient noise, with spectral levels closely tracking the NLNM across a broad frequency range. In contrast, surface stations (GAL, KETI, OKM, HPP), subject to greater environmental influence, exhibited elevated noise levels; however, these remained below the NHNM thresholds. These results confirm that the network achieves sufficiently low noise conditions to support reliable microseismic monitoring [1].

Analysis of Local Seismicity and Network Performance

The procedures for earthquake detection, location, and magnitude determination using the DAMAST network have been previously detailed in [1] and are not repeated here. In this study, we focus on the analysis of the resulting seismic dataset, with particular attention to the spatial distribution of events around the dam, magnitude distribution, and catalog completeness. Additionally, we examine statistical relationships among key earthquake parameters to better characterize the nature of the observed seismicity. These analyses aim to evaluate whether the recorded events are consistent with regional tectonic processes or exhibit anomalies potentially related to reservoir-induced effects.

Fig. 3(a,b,c,d) present an overview of the key statistical characteristics of the seismic catalog. Specifically, they show: (a) the distribution of earthquake epicenters as a function of distance from the dam (DFD), (b) the relationship between local magnitude (Ml) and DFD, (c) the number of events as a function of focal depth, and (d) the distribution of events by magnitude. From the distributions we observe that the DAMAST network is capable of detecting microearthquakes with local magnitudes (Ml) as low as -1 within approximately 5 km of the dam. Detection of events with $Ml < 0$ remains possible up to a distance of 17.7 km. Beyond this range, and up to ~30 km from the dam, only events with $Ml > 0$ are consistently recorded. The depth distribution indicates that the majority of events occur between 4 and 6 km, while the magnitude histogram shows a peak near $Ml = 0.3$, with an estimated uncertainty of approximately ±0.23. These distributions provide important constraints on the sensitivity limits of the network and the spatial characteristics of the local seismicity.

a)



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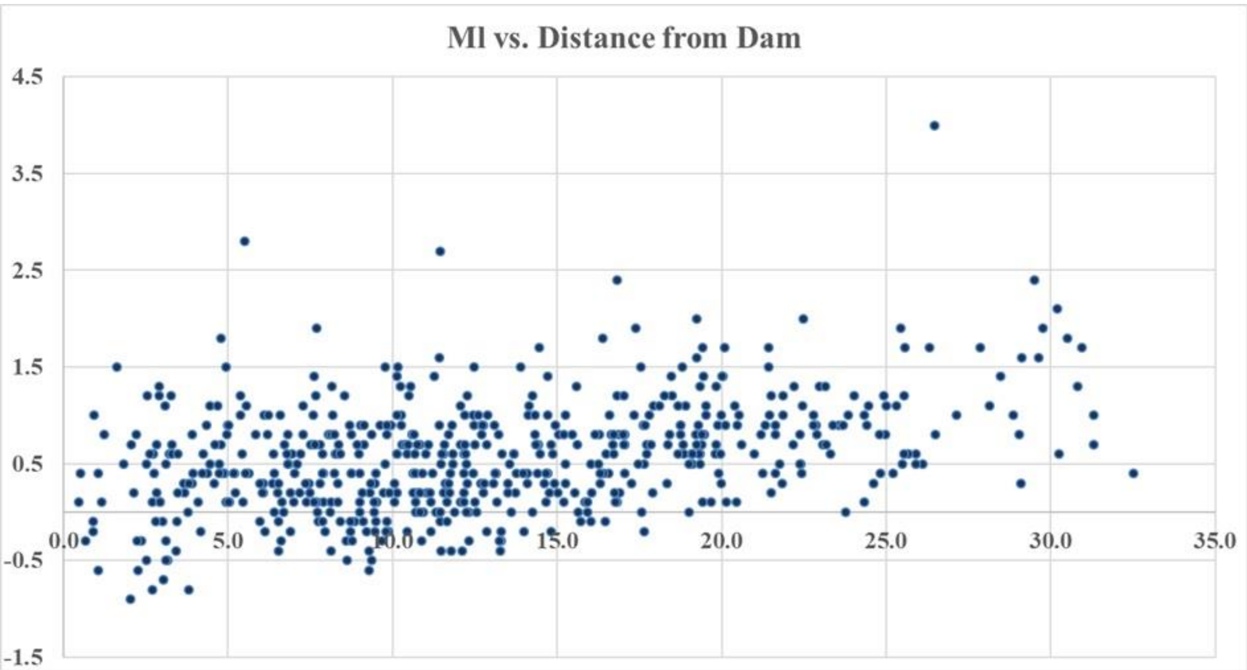

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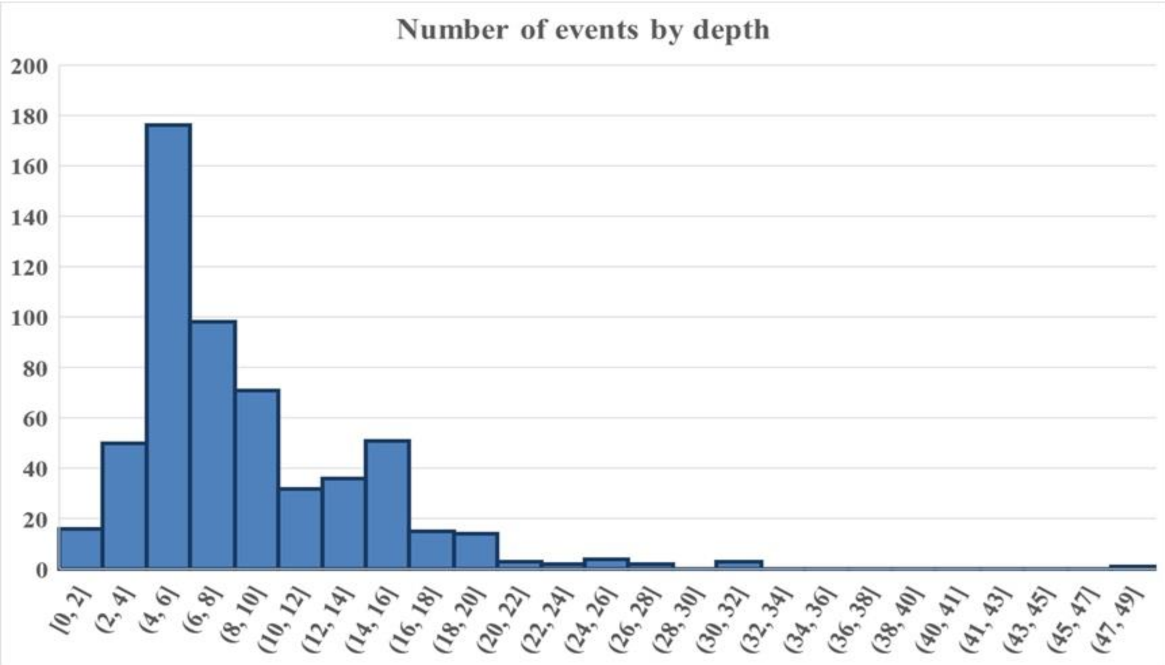

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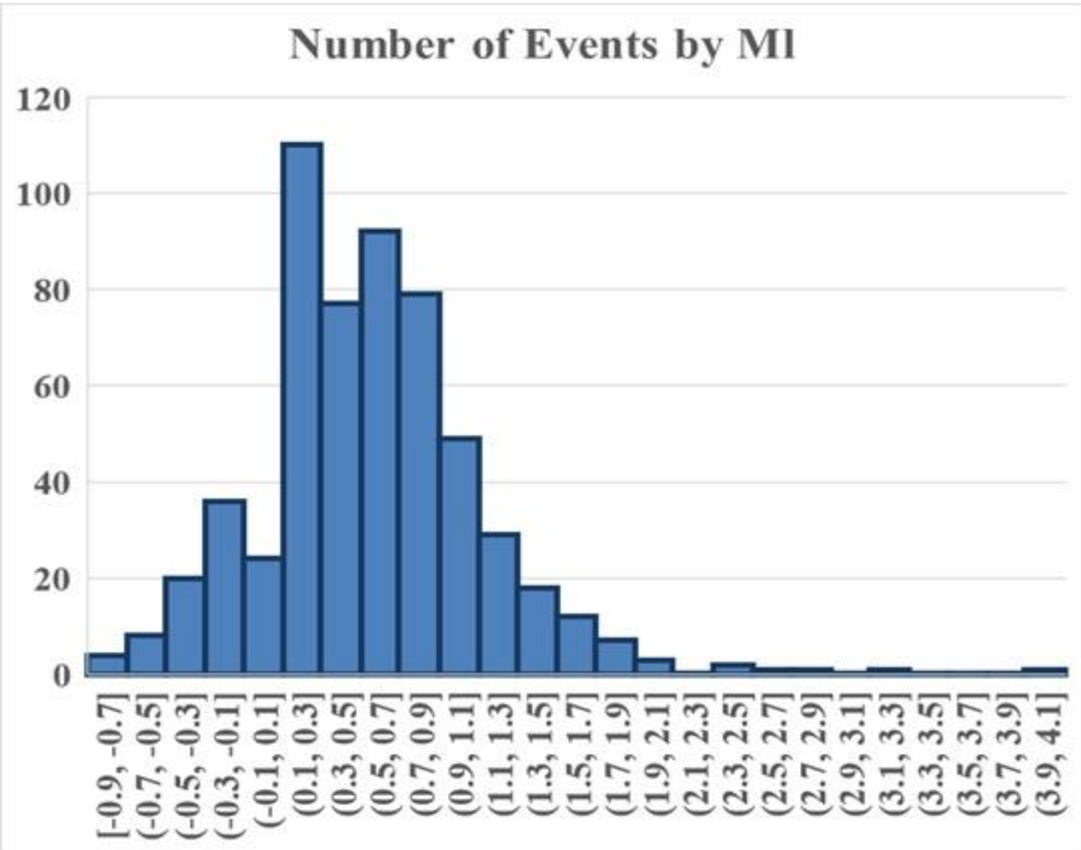
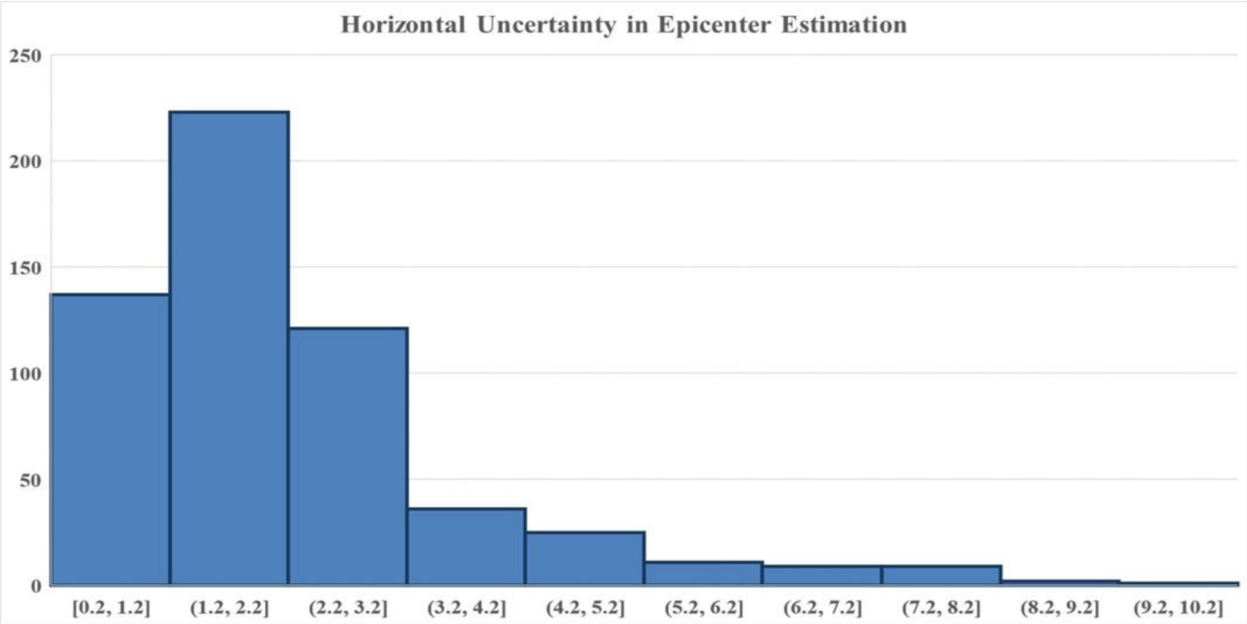


Fig. 3 a) Number of events by distance from Dam; b) Local magnitude (Ml) by distance from the dam (DFD);c) The number of events by focal depth; d) Number of events by magnitude.

In addition, we examined the horizontal and vertical location uncertainties of the recorded events, along with the azimuthal gap distribution. These parameters were analyzed with respect to event magnitude and are summarized in Figure 4 (a,b,c,d).

a)



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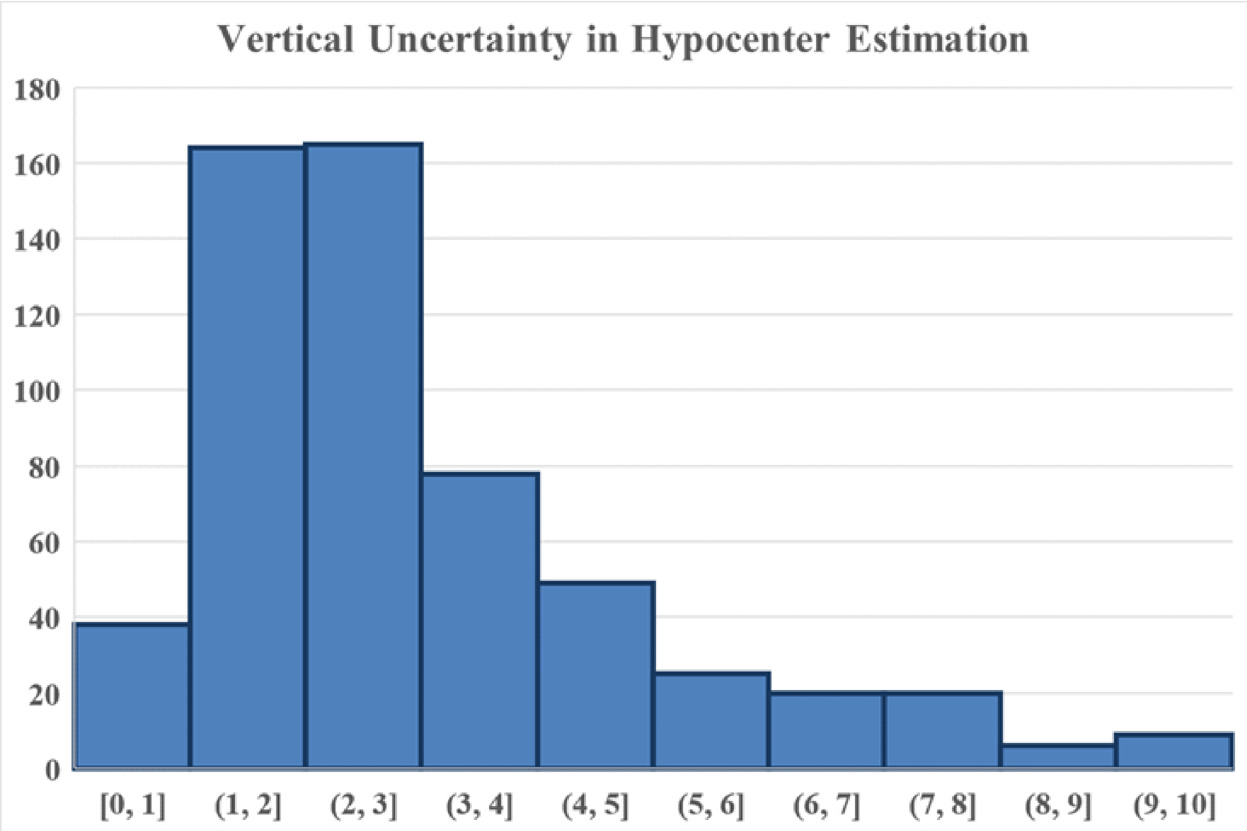

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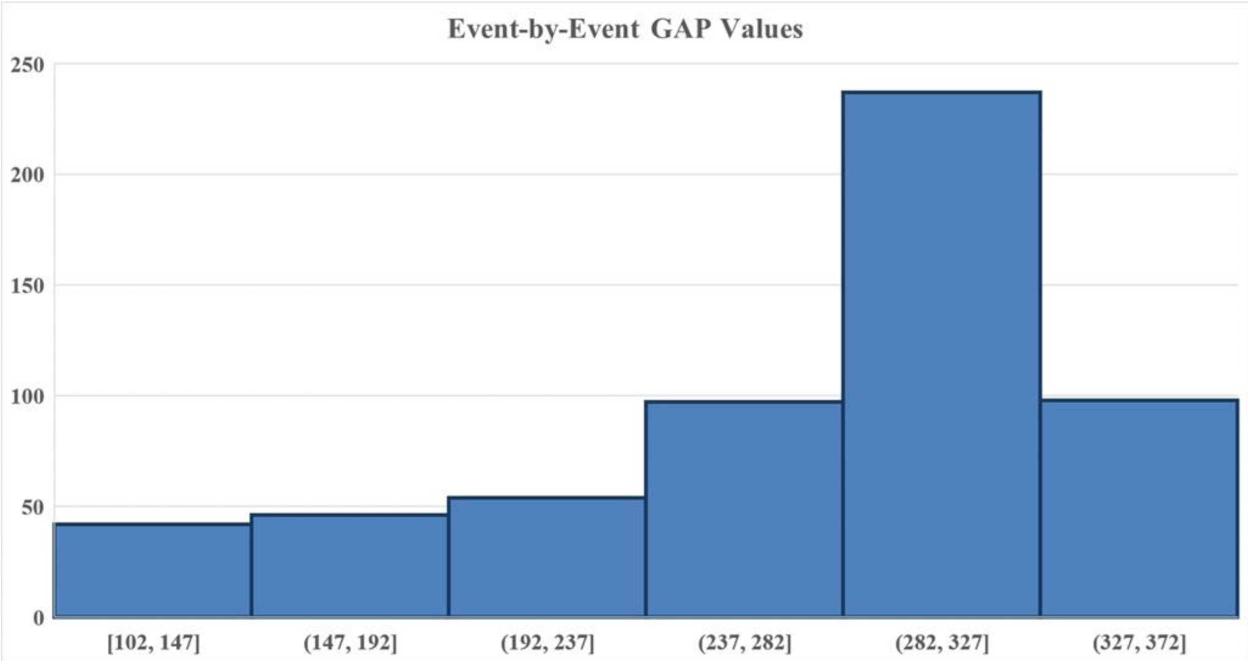

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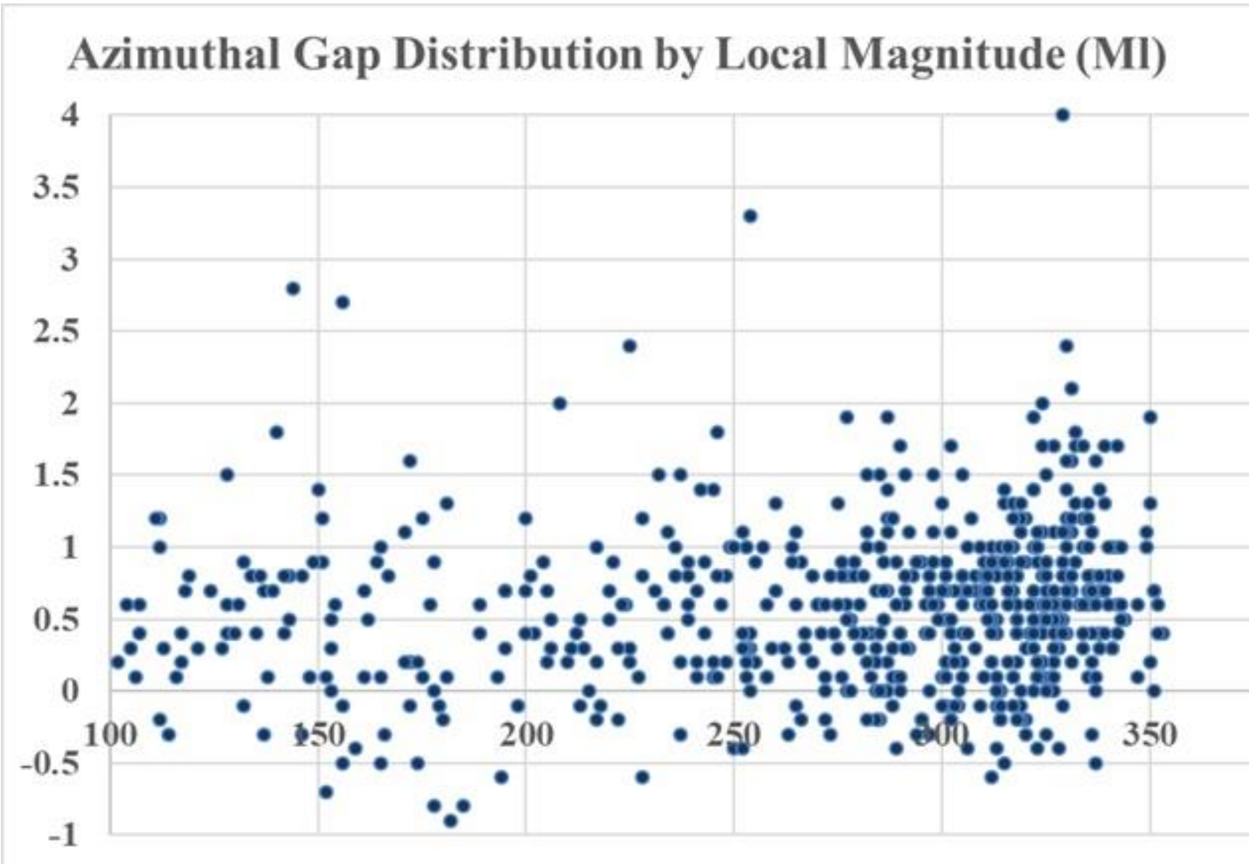

Fig. 4 a) The horizonla location uncertainties of the recorded events; b) The vertical location uncertainties of the recorded events; c) Azimuthal GAP of the recorded events; d) Azimuthal GAP distributin by Ml

The results show that horizontal and vertical estimation errors are below 5 km for the majority of events, indicating generally reliable hypocentral locations. However, azimuthal gaps are relatively high, often exceeding 222°, due to the spatial configuration of the network and the presence of inaccessible regions.

Despite this, events with Ml < 0 are still detected within these conditions, highlighting the network's sensitivity to low-magnitude seismicity even under suboptimal geometric coverage.

Completeness Magnitude and Gutenberg–Richter Analysis

To assess temporal variations in seismic monitoring performance and investigate possible hydrologically modulated seismicity, we analyzed the cumulative number of earthquakes over time. To determine an appropriate temporal resolution for estimating completeness magnitude (Mc) and tracking the evolution of microseismicity, we first estimated recurrence intervals for small-magnitude earthquakes using the Gutenberg–Richter (GR) relationship derived from the broader tectonic zone encompassing the Enguri Dam (Tab1).

Based on the national seismic catalog and applying the GR relation to events with Ml ≥ 3, we extrapolated the expected recurrence rates for lower-magnitude events. This analysis suggests that, according to the least-squares (LS) method:

• Earthquakes with Ml ≥ 2 occur approximately every 2.4 months,

• Events with Ml ≥ 1 occur in less than one month.

Estimates obtained from the maximum likelihood (ML) method suggest even shorter recurrence intervals. Considering these results and the typical 4-month duration of hydrological transitions (filling and drawdown) at the reservoir, we adopted a 3-month window for Mc estimation. This window size ensures statistical robustness while remaining sensitive to possible seasonal changes in detectability or seismic response associated with reservoir level fluctuations. In other words These recurrence intervals justify the chosen window size, which is sufficiently long to include multiple low-magnitude events yet short enough to resolve temporal changes in detection capability and seismic response.

To evaluate the detection threshold and temporal consistency of the local seismic catalog, we examined the cumulative number of earthquakes within a 0–17 km distance from the dam, using several magnitude bins and discrete time intervals. Preliminary analysis of the full dataset, aggregated in 3-month windows, revealed a noticeable change in the slope of the cumulative trend around April 2022 (Figure 5).

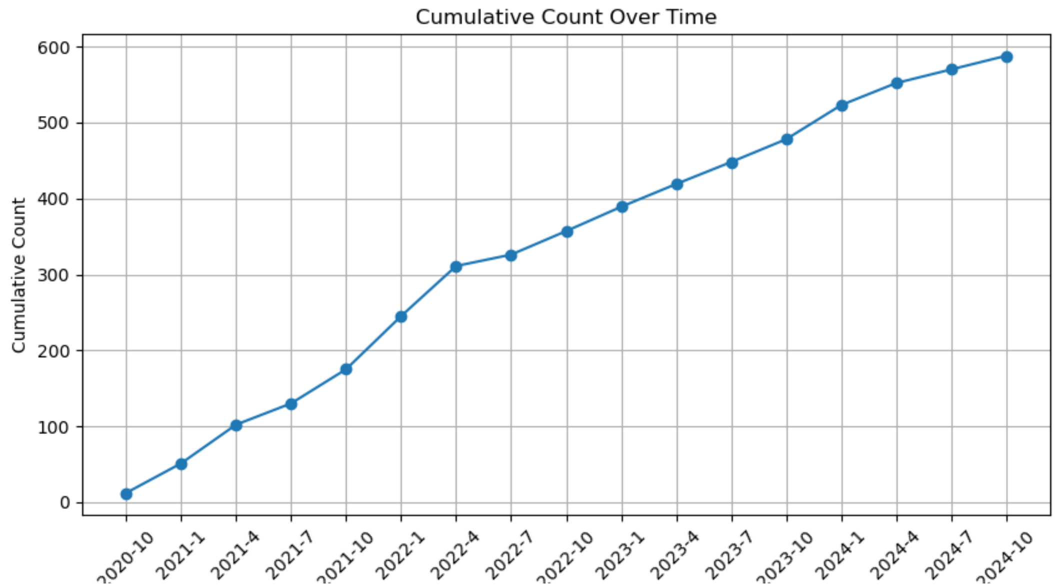

Fig. 5. The cumulative number of earthquakes within a 0–17 km distance from the dam aggregated in 3-month windows.

This feature is apparent for events with magnitudes up to Ml = 0; for Ml ≥ 0, the trend becomes linear and consistent , with only a minor deviation near April 2022, likely attributable to transient clustering rather than a systematic decline in detectability. The timing of this shift coincides with a transition in data processing responsibility-from German collaborators to a local student-raising concerns about possible inconsistencies in the detection or cataloging of low-magnitude events. Based on these findings, we conclude that the catalog can be complete for Ml >0.0, while detection reliability decreases for magnitudes below this threshold, particularly after April 2022.

To investigate whether the seismicity rate for these low-magnitude events has remained constant, we repeated the analysis using 12-month bins. This revealed a distinct flattening of the cumulative event curve after late 2023, despite the absence of any change in network operation or data processing methods. Since this trend is not observed in higher-magnitude bins (e.g., Ml ≥ 0.4), we interpret it as a real decline in the occurrence rate of smaller microearthquakes (Ml ≈ 0.0–0.3) since November of 2023 (Fig.6). This reduction may reflect stress relaxation following a previously more active phase, potentially driven by pore pressure diffusion or changes in reservoir-induced stress. Alternatively, it may signal progressive stress accumulation, in which small asperities have already ruptured and stress is increasingly focused on larger fault segments. This type of seismic quiescence has been reported prior to larger events in other tectonic and reservoir settings. Although additional analysis (e.g., clustering behavior, focal mechanism trends, or geomechanical modeling) would be required to test these scenarios, the current observations point to a genuine physical change in the system, rather than an artifact of detection or processing.

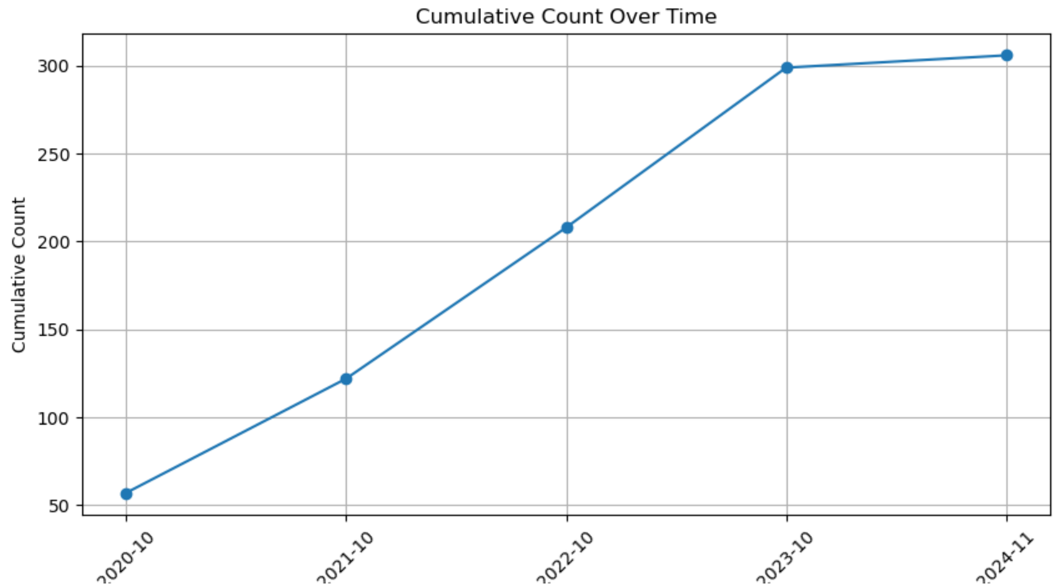

Fig. 6. The cumulative number of earthquakes within a 0–17 km distance from the dam aggregated in 12-month windows.

Catalog completeness was carefully assessed using both cumulative number analysis by magnitude and time and the MAXC method. Based on this analysis and on the discussion above, we adopt Mc = 0.6 as a conservative completeness threshold in the range 0–17 km.

To assess the spatial characteristics of seismicity around the Enguri Dam, we analyzed Gutenberg–Richter parameters within two distance ranges: 0–17 km, 0–30 km, using both least squares (LS) and maximum likelihood (ML) estimation methods. The results are summarized in Table 1. In particular, induced seismicity-often characterized by elevated b-values due to transient stress perturbations from reservoir fluctuations-may affect the observed distribution. In the 0–17 km range, the ML and the LS method gives b value ≥1. Completeness analysis for the broader 0–30 km region indicates a reliable threshold of Mc = 1.0, reflecting decreased sensitivity at larger distances. For this zone, LS yields b = 0.77, while ML gives b = 1.04

The Gutenberg–Richter law [3] describes a cumulative distribution of discrete earthquake magnitudes and is commonly expressed as:

$\log_{10}N(M)=a-bM$

where N(M) is the number of earthquakes with magnitude ≥ M, and a and b are constants characterizing the seismic productivity and the relative proportion of small to large events, respectively [2;5]. Accurate estimation of the b-value is essential for understanding the stress regime and failure characteristics of a given seismotectonic or anthropogenically influenced region.

The Maximum Likelihood Estimation (MLE) method provides an efficient, unbiased estimator for the exponential distribution of magnitudes above the completeness threshold Mc [6-7]. The MLE approach avoids the pitfalls of the Least Squares (LS) method, which assumes linearity in the log-transformed cumulative frequency–magnitude distribution and is highly sensitive to data binning, magnitude rounding, and departures from ideal power-law behavior [8-9]. This distinction is particularly relevant for the Enguri Dam region, where seismic catalog completeness may vary due to changes in network configuration, processing protocols, and temporal variations in ambient noise. In such environments, LS regression can significantly underestimate or overestimate the b-value, especially near the magnitude of completeness. The MLE method, by contrast, operates directly on the individual magnitudes and remains robust against these catalog limitations [8-9].

Furthermore, MLE allows for the derivation of analytical confidence intervals, enabling statistically rigorous comparisons across different spatial or temporal windows. This capability is critical in high-resolution microseismic studies, such as those conducted around large hydropower reservoirs, where subtle changes in seismicity may reflect stress perturbations or hydrologically induced pore pressure diffusion [11-13].

For comparison, the Gutenberg-Richter b-values derived from the national seismic catalog-homogenized to moment magnitude (Mw)-are notably lower than those obtained from the local catalog within both the 0–17 km and 0-30 km distance ranges around the Enguri Dam. While differences in magnitude scales can affect b-value estimation, particularly for low-magnitude events where Ml and Mw diverge, the consistently high b-values (≥ 1) obtained using Ml suggest that this discrepancy cannot be explained solely by the choice of magnitude type. Instead, the results likely reflect genuine local conditions, including the occurrence of a larger proportion of small-magnitude events and the influence of reservoir-induced processes. The similarity of b-values across both spatial ranges implies that the effects of reservoir operations-most notably water level fluctuations-may extend at least 30 km from the dam, supporting the interpretation that the observed seismicity is induced or significantly modulated by anthropogenic activity.

Table 1. The Gutenberg–Richter parameters for the seismogenic source were estimated from the national earthquake catalog using two approaches: the least squares (LS) method and the maximum likelihood method.

Mc	bin	Method	b-value	a-value	Range km	network
0.6(Ml)	0.2	LS	1.02	2.26	0-17	DAMAST
0.6(Ml)	0.2	ML	1.00	2.85	0-17	DAMAST
1.0(Ml)	0.2	LS	0.77	2.13	0-30	DAMAST
1.0(Ml)	0.2	ML	1.04	3.23	0-30	DAMAST
3.5(Mw)	0.2	LS	0.7	2.1		National
3.5(Mw)	0.2	ML	0.88	3.08		National

Hydro-Meteorological Controls on Monthly Seismic Activity

To evaluate the influence of short-term hydrological and meteorological processes on local seismicity, we analyzed monthly earthquake counts in relation to three key parameters: reservoir water level, water inflow, and the rate of water level change (velocity) (Fig.7-8). From early 2021 to mid-2022, the reservoir followed a regular seasonal cycle with gradual filling and drawdown phases and extended high- and low-water plateaus. During this period, elevated seismicity systematically coincided with the transition phases, consistent with classical models of hydro-mechanical triggering. Earthquake counts peaked at the end of drawdown in early 2021, again during reservoir filling in mid-2021, and most notably during and after drawdown in early 2022. These periods also coincide with significant water inflow peaks and positive or negative extremes in water level velocity, highlighting a coupled response to both volumetric and stress-rate changes in the system.

After July 2022, the dam's operational regime changed-high-water plateaus disappeared, and the reservoir exhibited faster and less symmetric cycling. The corresponding seismicity became less periodic and more scattered. Although seismic activity continued to respond at times to hydrological transitions, the relationship weakened, likely due to shortened stress-loading intervals, more abrupt pressure changes, and altered diffusion pathways within the crust.

Interestingly, a notable seismicity peak in January 2023 occurred without a sharp change in water level velocity. This suggests that not all triggering is driven by high stress rates; instead, it may reflect delayed rupture following earlier stress accumulation or unloading. In contrast, a period of high negative velocity around November 2023-indicative of rapid drawdown-was not accompanied by increased seismicity. This implies that the crustal system had either already released accumulated strain or was in a post-rupture relaxation phase. These observations emphasize that the triggering process depends not only on instantaneous stress changes but also on the temporal evolution of the stress field and fault memory effects.

Overall, the results point to a complex and evolving relationship between seismicity and hydrological forcing. While water level, inflow, and rate of change all appear to influence the timing and amplitude of microseismic activity, the underlying mechanism is ultimately rooted in stress perturbations caused by water level variations. However, the presence of both responsive and unresponsive phases, as well as asymmetries between loading and unloading, suggests that the system’s behavior is modulated by additional factors such as preexisting stress state, fault maturity, and potential fatigue or healing processes. Rather than supporting a single deterministic model, the observations imply a dynamic interplay between reservoir-induced stress changes and local fault stability conditions, with the seismic response being highly context dependent.

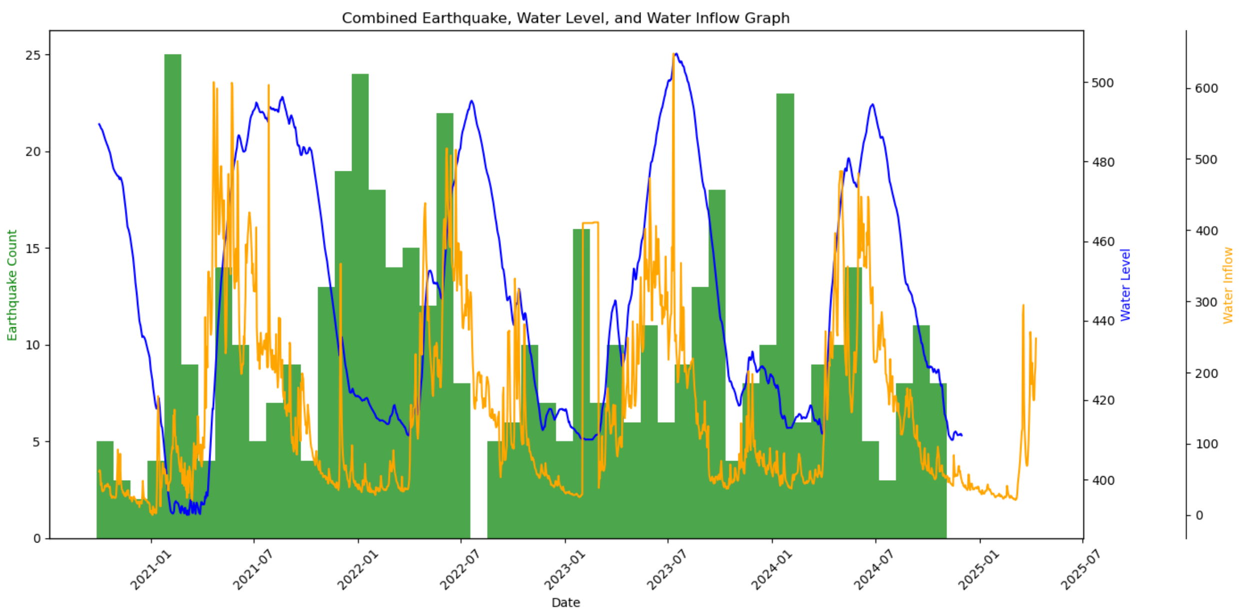

Fig. 7. Monthly Seismicity, Reservoir Water Level Changes, and Inflow at Enguri Dam.

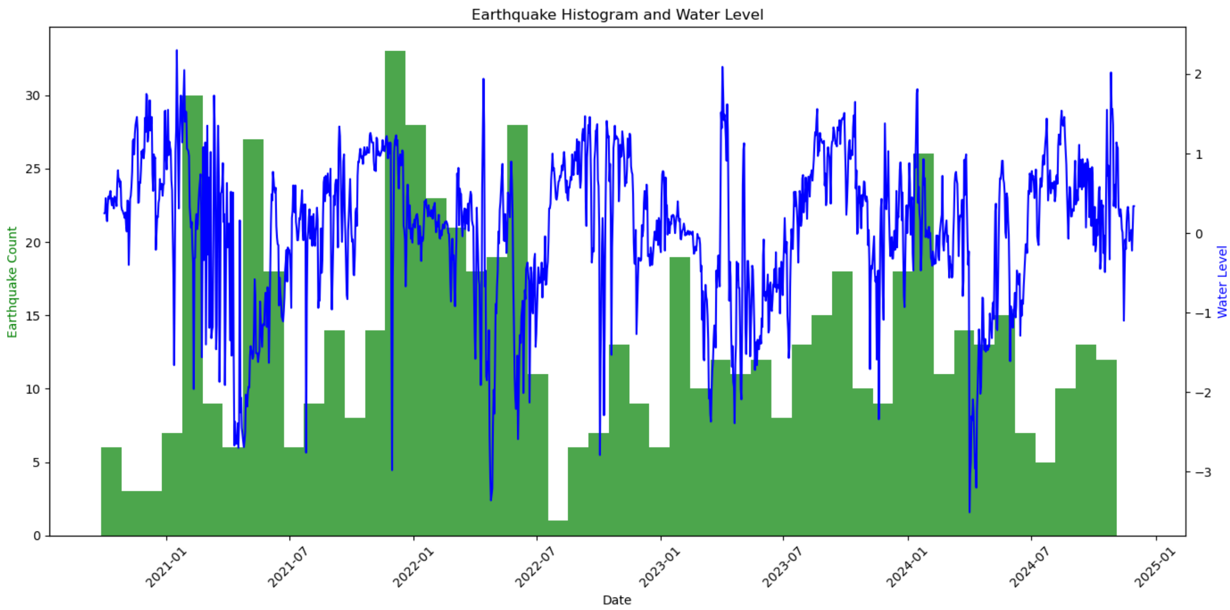

Fig. 8. Monthly Seismicity and Water Level Change Rate at Enguri Reservoir.

While hydrological controls exhibit a clear relationship with microseismicity, meteorological parameters-namely air temperature, humidity, and rainfall-show no consistent correlation with monthly earthquake rates (Fig 9-11). Although isolated coincidences exist, seasonal temperature cycles and short-lived rainfall or humidity fluctuations do not align systematically with seismicity peaks. This suggests that atmospheric variables are not primary drivers of stress changes at seismogenic depths. Their influence, if any, is likely indirect-manifesting through surface runoff and infiltration processes already reflected in inflow and reservoir level dynamics.

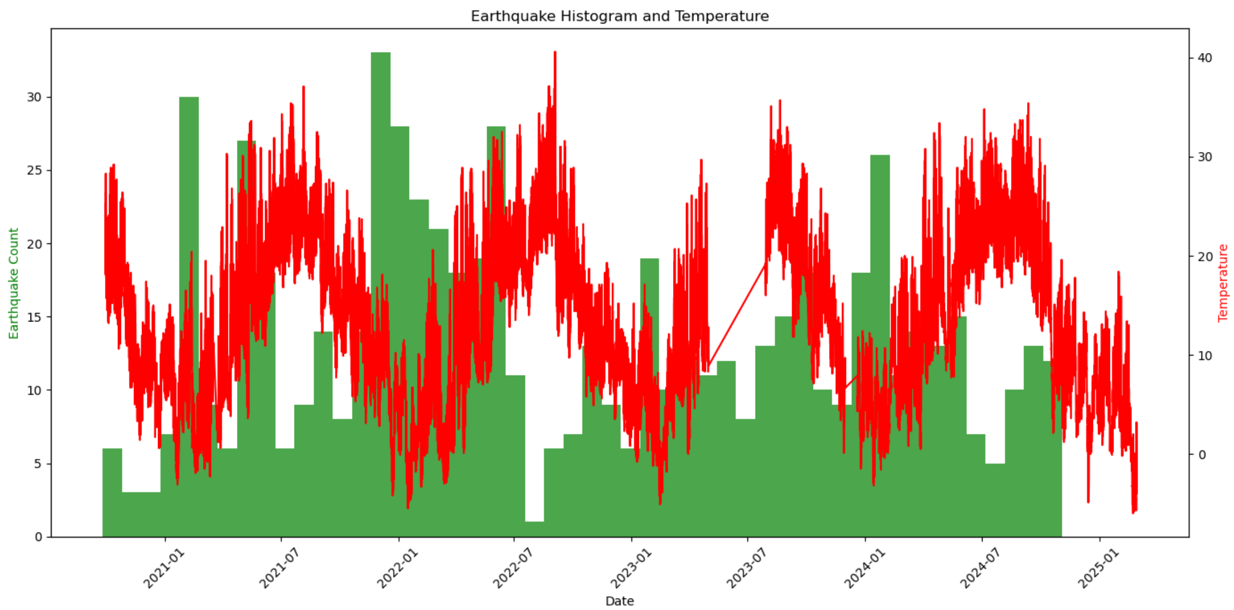

Fig. 9. Monthly Seismicity and Temperature Changes.

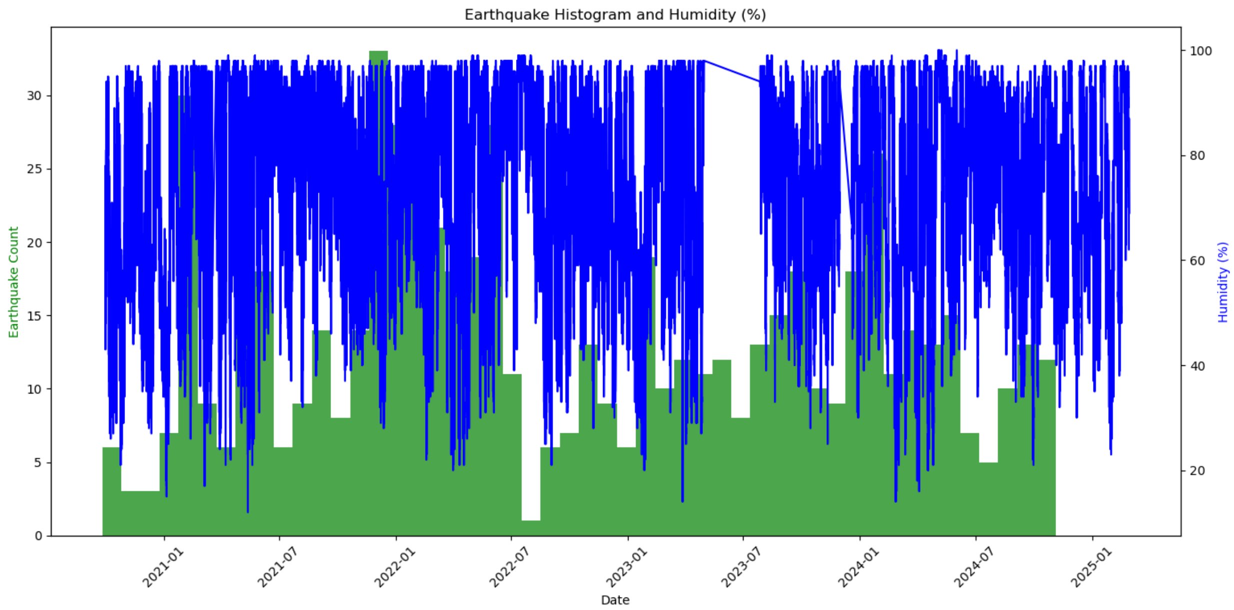

Fig. 10. Monthly Seismicity and Humidity Variations.

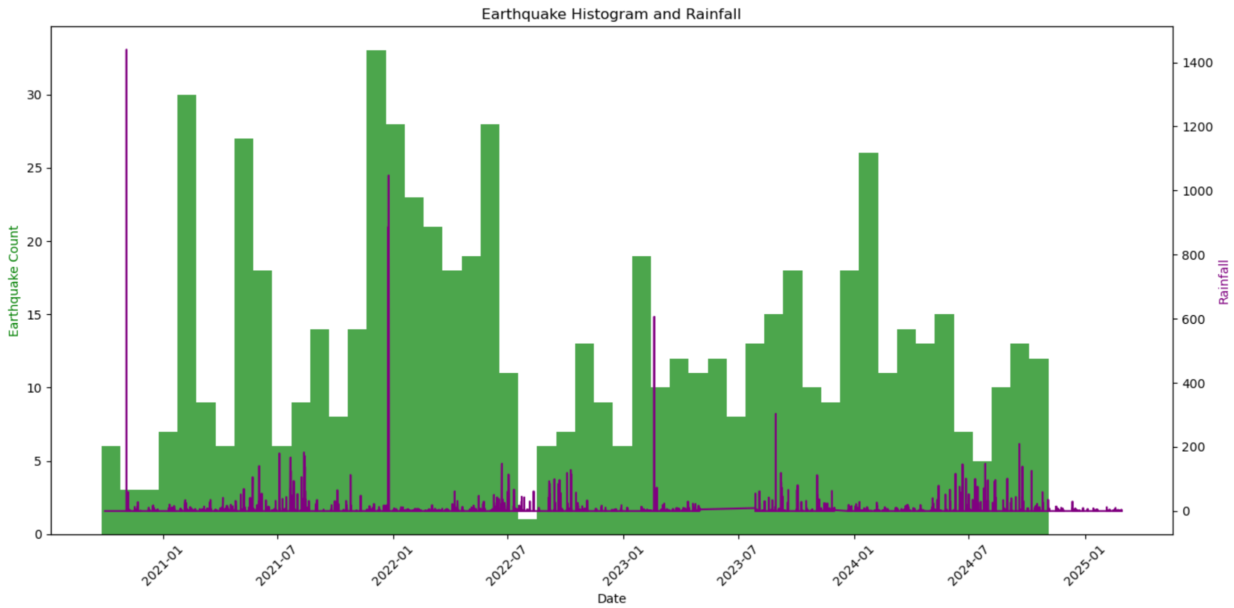

Fig. 11. Monthly Seismicity and Precipitation.

Conclusion

The DAMAST microseismic catalog [14] provides a unique opportunity to study reservoir-induced seismicity near the Enguri Dam with high resolution. Catalog completeness was carefully assessed using both cumulative number analysis by magnitude and the MAXC method, leading to a conservative completeness magnitude of Mc = 0.6 within a 17 km radius of the dam. This threshold enabled robust estimation of Gutenberg–Richter parameters, revealing elevated b-values, indicative of a relatively high proportion of low-magnitude events. These findings contrast with lower b-values derived from the national Mw-based catalog for the same tectonic zone, suggesting that local processes-including reservoir operations-may be influencing the microseismic population. The similarity of b-values across both spatial ranges implies that the effects of reservoir operations-most notably water level fluctuations-may extend at least 30 km from the dam, supporting the interpretation that the observed seismicity is induced or significantly modulated by anthropogenic activity

The temporal evolution of seismicity further supports this interpretation. During periods of regular reservoir operation (2021–mid-2022), seismicity rates increased during both water level rise and drawdown phases, consistent with expected stress changes due to volumetric loading and unloading. This behavior aligns with the elevated b-values, often associated with induced seismicity in response to transient stress perturbations.

Following a shift in reservoir management after mid-2022, the seismic response became less periodic and more irregular, yet still showed isolated peaks temporally correlated with rapid water level transitions. This pattern supports a continued, though more complex, hydro-seismic interaction. In contrast, meteorological parameters such as temperature, humidity, and rainfall showed no meaningful correlation with seismicity, reinforcing the conclusion that stress changes from water level variation are the primary modulating factor.

Overall, the integration of statistical seismological analysis with hydrological and meteorological records reveals that microseismicity near the Enguri Dam is closely linked to reservoir-induced stress changes. The combination of elevated b-values, spatiotemporal clustering, and correlation with water level dynamics points to induced processes operating alongside regional tectonic background activity.

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ენგურის კაშხლის (საქართველო) მიმდებარე ტერიტორიაზე მიკროსეისმური აქტივობის დროითი ცვლილება წყალსაცავის ექსპლუატაციის გავლენის ფონზე

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რეზიუმე

წარმოდგენილ ნაშრომში განიხილება მიკროსეისმურობის დროით-სივრცული ანალიზი ენგურის კაშხლის (საქართველო) მახლობლად, DAMAST პროექტის ფარგლებში დამონტაჟებული ადგილობრივი სეისმური ქსელის ოთხ წელზე მეტი ხნის მონაცემების საფუძველზე. კატალოგის სისრულის ანალიზის საფუძველზე, წარმომადგენელი მიწისძვრის მაგნიტუდა განისაზღვრა, როგორც Mc = 0.6 კაშხლიდან 17 კმ რადიუსში, რაც შესაძლებელს ხდის გუტენბერგ–რიხტერის პარამეტრების სანდო შეფასებას. DAMAST-ის კატალოგის მიხედვით მიღებული მაღალი b-მნიშვნელობა, ეროვნულ კატალოგზე მიღებულ b-მნიშვნელობაზე, მიუთითებს, რომ სეისმურობის მნიშვნელოვანი ნაწილი შესაძლოა კაშხლის ექსპლუატაციით იყოს გამოწვეული. მსგავსი ანალიზის შედეგად, 30 კმ რადიუსში გამოვლინდა, რომ კატალოგის სისრულის ზღვარი შეესაბამება Mc = 1.0-ს, თუმცა მაქსიმალური მსგავსების მეთოდით შეფასებული b-ის მნიშვნელობა კვლავ მაღალია (≥ 1). b-ს ამგვარი მაღალი მნიშვნელობის სივრცული ერთგვაროვნება მიუთითებს, რომ რეზერვუარის ექსპლუატაციას აქვს გავლენა სეისმურობაზე მინიმუმ 30 კმ რადიუსში კაშხლისგან. კვლევამ აჩვენა, რომ სეისმური აქტივობის ზრდა ძირითადად ემთხვევა წყალსაცავის შევსებისა და დაცლის პერიოდებს, მაშინ როდესაც მეტეოროლოგიურ პარამეტრებთან სტატისტიკურად მნიშვნელოვანი კავშირი არ აღინიშნება. ჩვენი შედეგები ხაზს უსვამს კაშხლის მუშაობით გამოწვეული დაძაბულობის ცვლილებების როლს მიკროსეისმურობაზე და აჩვენებს, რამდენად მნიშვნელოვანია უწყვეტი ჰიდროლოგიური და სეისმოლოგიური მონიტორინგის ინტეგრაცია მსგავსი სახის ინფრასტრუქტურის სეისმური რისკების შეფასებისთვის.

საკვანძო სიტყვები: მიკროსეიმურობა, ენგურის კაშხალი, სეისმური კატალოგის ანალიზი,b-ფაქტორის შეფასება

Эволюция микросейсмичности во времени в ответ на эксплуатацию водохранилища у плотины Ингури (Грузия)

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Резюме

В настоящем исследовании анализируется временная эволюция микросейсмичности в районе плотины Ингури (Грузия) на основе более чем четырехлетних данных, собранных локальной сейсмической сетью, установленной в рамках проекта DAMAST. Подробный анализ полноты каталога позволил определить консервативный порог $Mc = 0.6$ в радиусе 17 км от плотины, что обеспечило надежную оценку параметров Гутенберга–Рихтера. Повышенные значения параметра b в локальном каталоге - по сравнению с данными национального каталога, приведённого к шкале моментной магнитуды (Mw) - указывают на возможное влияние процессов, вызванных эксплуатацией водохранилища. При расширении анализа до радиуса 30 км установлено, что порог полноты увеличивается до $Mc = 1.0$; однако значение b остаётся высоким (≥ 1) при использовании метода максимального правдоподобия. Такое пространственное постоянство повышенных значений b свидетельствует о том, что эксплуатация водохранилища оказывает влияние на сейсмичность на расстоянии как минимум 30 км от плотины. Сейсмичность коррелирует с изменениями уровня воды, особенно в фазах наполнения и спуска, тогда как метеорологические параметры не демонстрируют устойчивой связи. Полученные результаты подчеркивают влияние работы водохранилища на микросейсмическую активность и важность комплексного мониторинга гидрологических и сейсмических процессов в районах крупных гидротехнических сооружений.

Ключевые слова: микросейсмичность, Ингурское водохранилище, анализ сейсмического каталога, оценка b-параметра