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Seismology and Earthquake Science:
links to marine geophysical investigations
and fluid-induced seismicity

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Abstract Book

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Orals

Regional Seismo-Acoustic Phase Generated by Thermospheric Returns from Large Chemical Explosions

Asaf Inbal, Leah Langer

Department of Geophysics, Tel Aviv University

Large chemical explosions generate infrasonic waves that can return to the Earth's surface through refraction in the altitude-dependent atmospheric sound-speed profile. Thermospheric returns are well documented by infrasound observations, but their seismic signatures remain poorly understood. Here, we report a previously unrecognized seismo-acoustic phase generated by the air-to-ground coupling of thermospheric acoustic returns from explosions in the Eastern Mediterranean. The phase is characterized by remarkably coherent long-period (0.02–0.04 Hz) ground motions recorded by broadband seismic stations located hundreds of kilometers apart. Infrasound array analysis is used to infer the horizontal slowness and duration of the incident pressure pulse, while observations from a collocated seismometer demonstrate that the seismic response is induced by the passing pressure front. Despite this direct causal relationship, the characteristic seismic frequency is two orders of magnitude lower than that of the incident acoustic pressure pulse. Preliminary analysis suggests the pressure-pulse geometry is responsible for this frequency mismatch. These observations demonstrate that thermospheric acoustic returns can generate detectable coherent regional seismic signals and provide new constraints on atmosphere-solid Earth interactions.

Kinematics of active strike-slip and strain partitioning in the northern Levant Basin: Evidence from instrumental seismicity

Nadav Wetzler[1], Eshly Aizenshtat Soffer[1,2], Uri Schattner[3], Amir Sagy[1]*

1 The Geological Survey of Israel, Jerusalem

2 Hebrew University, Jerusalem, Israel

3 School of Environmental Sciences, University of Haifa, Israel

A 16-year dataset of instrumental seismicity (2010–2026) characterizes the active tectonic regime of the northern Levant margin in offshore Lebanon. Our focal mechanism analysis reveals that regional deformation is predominantly accommodated by dextral strike-slip

reactivation along inherited Mesozoic structures, specifically the Tripoli-Batroun, Jounieh, and Damour fault systems. These findings demonstrate that modern strain release is concentrated within this strike-slip network rather than primarily on large-scale thrust fronts. In addition, our observations in the continental shelf of north Israel suggest that the Carmel-Yagur fault system, which were mainly developed as normal fault until the Pliocene, might serves in modern days as a critical active structural boundary that facilitates the transfer of transpressional strain from the onshore Galilee domain into the offshore continental shelf. Consequently, our results necessitate a re-evaluation of regional seismic hazard assessments, which should prioritize these active strike-slip systems to accurately characterize the seismic potential of the northern Levant Basin.

Rupture directivity - Insights from theoretical studies applied to observations

Ittai Kurzon[1], Linoy Grinberg[1,2], Itzhak Lior[2]

1) Geological Survey of Israel, Jerusalem, Israel

2) The Hebrew University of Jerusalem, Jerusalem, Israel

Rupture directivity is a seismic source property reflecting the dynamics of the rupture process. When ruptures exhibit a clear sense of direction, they generate asymmetric radiation patterns in seismic amplitudes and corner frequencies, an effect first described analytically by Ben-Menahem (1961) as a moving point-source. Subsequent numerical studies (Kurzon et al., 2019, 2021) demonstrated that incorporating source-volume, damage, and rheological complexity, significantly improves the representation of rupture processes, and that in many cases P-wave radiation patterns are more stable and indicative of rupture directivity than S-waves.

Here, we examine these numeric insights against field observations using a unique dataset of 31 earthquakes (Mw 2.5–4.5) from a seismic swarm in the Sea of Galilee. The events were recorded by ~30 stations with good azimuthal coverage, enabling robust assessment of rupture directivity and rupture properties. Our results show that (1) most events exhibit clear rupture directivity; (2) P-waves display stronger and more consistent directivity than S-waves, in agreement with numerical simulations; (3) S-waves generally show weaker directivity, but agree with P-waves inferred signatures; and (4) rupture propagation is predominantly toward the SE–SSE, compatible with an east-trending oblique fault. In addition, by quantifying the directivity strength from the radiation patterns, we may estimate rupture velocities as V_r/V_s = 0.65–0.95; S to P energy ratio as ~5–15; and S-wave energy loss of ~20–60% during rupture.

Our results validate the numerical simulations and demonstrate the ability to infer dynamic rupture properties for small earthquakes.

3D Physics-Based Earthquake Simulations of Unique Geological Features in Northern Israel and their Effect on the Seismic Hazard

Ronnie Kamai[1,2], Amany Abu-Assa[2], Nevo Shachrur[2] and Michael Tsesarsky[1,2]

(1) Department of Civil and Environmental Engineering, Ben Gurion University of the Negev, Beer-Sheva, Israel.

(2) Department of Earth and Environmental Sciences, Ben Gurion University of the Negev, Beer-Sheva, Israel.

The geological structure along the northern sections of the Dead-Sea Fault system exhibits pronounced spatial heterogeneity at short length scales. Deep pull-apart basins, filled with soft sediments, and bounded by sharp velocity contrasts, form along the active plate boundary. The rupturing of a long-vertical strike-slip within such structures - leads to unique effects, such as directivity, super-shear, waveguide, and basin amplification – all superimposed within the resulting ground motions. These unique effects are not captured by global ergodic ground motion models (GMMs), which are used in local seismic hazard analysis (SHA), due to the low seismicity rates and sparse recordings of moderate to large earthquakes.

Physics-based simulations are employed in this study to address this challenge and allow for a better understanding of expected ground motions. The SW4 finite-difference code is used together with a detailed 3D velocity model of the area, which includes the main geological features. Nine Mw7.0 rupture scenarios on three fault segments of the northern DSF are simulated, varying only the location of rupture initiation. The simulations generate a comprehensive synthetic database of over 32,000 three-component seismograms, enabling systematic quantification of source, path, and site effects on ground motions.

The results demonstrate that rupture directivity, waveguide, and basin amplification interact strongly, producing spatially concentrated zones of elevated shaking, pronounced component-specific ground-motion directionality, and increased durations within the major basins. These findings highlight the importance of incorporating three-dimensional geological heterogeneity into seismic hazard assessment and provide a physics-based framework for improving earthquake-resistant design and resilience planning in Israel.

How effective normal stress oscillations advance failure in fault gouge: frequency dependence, non-failure window, and the role of dilation

Einat Aharonov[1,2], Pritom Sarma[1], Renaud Toussaint[2,3], Stanislav Parez[4,5]

1) Institute of Earth Sciences, Hebrew University of Jerusalem, Jerusalem, Israel

2) The Njord Centre, Departments of Physics and Geosciences, University of Oslo, Oslo, Norway

3) Université de Strasbourg, CNRS, ENGEES, Institut Terre et Environnement de Strasbourg, UMR7063, Strasbourg, France

4) Faculty of Science, Jan Evangelista Purkyně University, Ústí nad Labem, Czech Republic

5) Faculty of Science, Charles University, Prague, Czech Republic

Cyclic pore-pressure and normal-stress variations occur during earthquakes and in engineered subsurface systems, yet the effect on fault stability and underlying mechanism remains poorly constrained. We use a coupled granular/fluid dynamics model to simulate a sheared, gouge-filled fault, subjected to effective normal-stress oscillations over 0.5–10^4 Hz. We compare dry and fluid-saturated, and impose oscillations by cycling pore pressure or, equivalently, normal stress, while keeping the peak stress state below the Mohr–Coulomb failure threshold measured in monotonic loading.

Despite this subcritical loading, failure occurs across most frequencies and depends non-monotonically on oscillation frequency. A distinct non-failure window emerges at intermediate frequencies, ~30–200 Hz, bounded by failure at lower and higher frequencies, and the response spans regimes from cyclic failure-and-arrest to continuous sliding. Pore-pressure and normal-stress cycling produce the same regime structure, consistent with Terzaghi's principle; fluid coupling mainly introduces a delay associated with dilatant hardening.

Subcritical failure arises via dilation-induced strength-deterioration through two mechanisms: At low frequencies, cycles allow shear-driven ratcheting dilation to accumulate. At high frequencies, dynamic dilation, acoustic-fluidization-like behavior, is promoted by amplified seepage forces, stress gradients, and inertial effects. The intermediate non-failure window marks the gap between these mechanisms. Our results identify frequency as a controlling parameter for granular fault stability, with implications for dynamic earthquake triggering and cyclic injection protocols.

From Aseismic Creep to Dynamic Rupture: A Fully Coupled Hydro-Mechanical Model of Reservoir-Induced Seismicity

Xiongjie Zhou, Regina Katsman

The Dr. Moses Strauss Department of Marine Geosciences, Leon H. Charney School of Marine Sciences, The University of Haifa

Reservoir-induced seismicity (RIS) arises from the coupled effects of reservoir loading, pore-pressure diffusion, and fault reactivation, yet their interactions remain incompletely understood. We present a fully coupled two-dimensional poro-visco-elasto-dynamic finite-element model for simulating RIS, implemented in COMSOL Multiphysics. The model integrates poroelasticity, dynamic solid deformation, frictional contact governed by rate-and-state friction coefficient, lower-dimensional fluid flow along permeable faults, and adaptive time stepping, to capture both long-term aseismic reactivation and rapid coseismic rupture within a unified framework.

The numerical implementation is verified against benchmark solutions for poroelastic consolidation, frictional contact, and spring-slider stick-slip behavior, demonstrating accurate hydro-mechanical coupling and fault friction evolution. Additional validation confirms stable and physically consistent simulation of dynamic rupture propagation and pore-pressure-dependent fault reactivation.

Simulations reproduce the complete sequence of fault activation, including aseismic creep, earthquake nucleation, and asymmetric dynamic rupture. Reservoir impoundment accelerates fault activation through coupled pore-pressure diffusion and poroelastic stress redistribution, modifying both effective normal stress and shear stress on the fault. Comparison of extensional and compressional tectonic settings shows that extensional loading promotes fault activation at substantially lower tectonic loading rates, whereas compression suppresses instability through increased fault clamping. Under rapid impoundment, however, reservoir-induced stress perturbations can oppose the stabilizing effect of compression and eventually alter the preferred slip tendency. The proposed model provides an efficient and physically consistent tool for investigating the mechanisms governing RIS and assessing fault stability under coupled hydraulic and tectonic loading.

How does material structure affect onshore and offshore displacement during subduction zone earthquakes?

Leah Langer

Tel Aviv University

The M9.1 2011 Tohoku earthquake occurred in a region with complex heterogeneous Earth structure, including non-uniform slab geometry and strong velocity contrasts. Some prior studies of the deformation caused by this earthquake have utilized 2.5-D or 3D material geometry, but the question of which material structures impact surface deformation remains unsettled. Here, we present an analysis of the Tohoku earthquake deformation field based on the Japan Integrated Velocity Structure Model (JIVSM). We analyze predicted surface displacement patterns for the Tohoku earthquake calculated with the JIVSM and with a suite of other models designed to be similar to those utilized in prior studies. We find that discrepancies on onshore displacements are significant, but even larger differences are present offshore, where none of the other models are able to replicate the shape of surface deformation predicted by the JIVSM. This discrepancy is likely due to the low-rigidity near-trench accretionary wedge which is present in the JIVSM but not in the other models. Our findings suggest that structural variations typical of subduction zone regions may significantly impact both the magnitude and distribution of surface deformation. Consequently, failure to account for heterogeneous material structure can systematically bias slip estimates for subduction zone earthquakes. The large offshore discrepancies will likely lead to even more significant bias when seafloor geodetic data are integrated into displacement analysis. In light of these results, it may be appropriate to re-visit conclusions drawn from prior analysis of geodetic data for the Tohoku earthquake.

<u>The effect of fault-zone damage geometry on earthquake rupture regimes: experimental observations</u>

Sauparna Ghosh, Gopala Krishna Rodda, Yuval Tal

Ben Gurion University of The Negev

Crustal faults are commonly surrounded by fracture-dominated damage zones that reduce seismic wave speed and alter the mechanical properties of the surrounding media. Although theoretical and numerical studies have suggested that such damage zones can influence earthquake rupture dynamics and may sustain supershear rupture in large earthquakes, direct experimental constraints remain limited.

Here, we present direct experimental evidence of how damage width and geometry play crucial roles in modulating earthquake rupture dynamics. Using laser-engraving techniques, we introduced structurally controlled damage zones into polymethyl methacrylate (PMMA) plates containing a pre-cut planar fault. We investigate various damage geometries, focusing on arrays of sub-parallel cracks with different spacings and widths.

We generate spontaneously propagating shear ruptures along the main faults and image the rupture using an ultra-high-speed camera operating at one million frames per second. By employing Digital Image Correlation (DIC) techniques, we characterize the ruptures with full-field maps of displacement and velocity.

We find that damage-zone width governs rupture dynamics, with sufficiently wide damage zones promoting a transition to supershear rupture, whereas narrower zones preserve sub-Rayleigh, pulse-like propagation and slightly reduce rupture speed. This behavior is consistent with rupture-generated seismic waves repeatedly interacting with wide damage zones, providing dynamic feedback that promotes supershear rupture. Crack orientation plays a secondary role by modulating the supershear transition distance.

These results provide direct experimental constraints on how fault-zone damage controls earthquake rupture regimes and suggest that progressive damage accumulation over multiple earthquake cycles may shift faults toward conditions favoring supershear rupture and its associated strong ground motion.

Microstructural evidence for seismic event/s in calcite-rich fault; New insights from the North Anatolian Fault

Yuval Boneh[1], Tsafrir Levi[2], Perach Nuriel[3], and Rami Weinberger[2]

1 Ben-Gurion University of the Negev; 2 Geological Survey of Israel; 3 University of Geneva

Evidence for the nature of fault slip throughout the seismic cycle is difficult to decipher. Apart from the rare occurrence of fault melt (i.e., pseudotachylytes), there is no unambiguous microstructural signature that uniquely records a seismic event. While considerable focus has been placed on characterizing deformation through fracturing and mesoscale structures, the analysis of grain-scale plastic processes has been largely neglected.

Here, we present a detailed microstructural analysis of carbonate samples from the North Anatolian Fault Zone. We used Electron Backscatter Diffraction to map the calcite grains' orientations and characterize intragrain damage and grain-boundary morphologies. These observations demonstrate that transient temperature increases from frictional heating can modify existing calcite-rich microstructures through intragrain damage and subsequent recovery processes. We infer that deformation mechanisms vary systematically with distance from the fault surface. Up to 0.5 mm from the fault surface, deformation is accommodated by brittle, cataclastic flow. The microstructure below is controlled by plastic deformation and recovery via grain growth (under static conditions). The most striking microstructural record is preserved in a layer 2-3 mm thick (about 1 mm from the fault surface), which initially shows strong evidence of recovery through abnormal grain growth. We propose that this latter process occurred during or immediately after coseismic frictional heating, consuming previously deformed grains and thereby preserving the crystallographic preferred orientation record of deformation, providing diagnostic evidence of the seismic cycle at millimeter-scale distances from the fault surface.

Monitoring the Lowest Place on Earth with Lake Bottom Fiber Optics Above the Dead Sea Fault

Itzhak Lior [1], Ariel Lellouch [2], Nadav Lensky [3], Omri Volk [1], Yevhenii Fedorchenko [1], Shahar Ben Zeev [4], Yovel Netanyahu [1], Nadav Kashtan [1], Gali Shraiber [1], Eyal Shimony [2], Aleksei Nelaev [2], Gil Noy [4], Tomer Harrary [4], Ittai Kurzon [3]

[1] The Institute of Earth Sciences, The Hebrew University, Jerusalem, Israel

[2] The Department of Environment and Earth Sciences, Tel Aviv University, Tel Aviv, Israel

[3] The Geological Survey of Israel, Jerusalem, Israel

[4] Prisma Photonics, Tel Aviv, Israel

The Dead Sea Transform (DST) is the most active fault system in Israel, accommodating an overall left lateral relative motion of ~5 mm/yr and generating destructive earthquakes throughout history, with an average of a M6+ every ~100 years; the last was the 1927 M6.2 earthquake near the Dead Sea. The recent upgrade of the national TRUAA earthquake early warning seismic network significantly enhanced monitoring abilities in the Dead Sea region, yet stations are exclusively located onland, leaving the Dead Sea seabed unmonitored. This monitoring gap limits the detection of microseismicity and the quantification of seismic rates in the region, and hinders the mapping of the fault system beneath the seabed. To allow the detection of microseismicity, map active faults and better quantify the tectonic behavior of the region, we have recently (July 2026) installed a 55 km long fiber at the bottom of the Dead Sea to be used as a dense seismic array via the novel technology of Distributed Acoustic Sensing (DAS). The cable was deployed in four segments from a vessel and spliced at sea. The Prisma Photonics interrogator unit is placed in a climate-controlled container near the shoreline and temporal sampling is set to 1800 Hz, channel distance is 9.1 m and the gauge length is 18.2 m. The fiber covers the northern Dead Sea basin in a zig-zag pattern, aiming to intersect as many active faults as possible, generate an optimal array response for event location, and mitigate DAS broadside sensitivity. The fiber was deployed starting from the

north-western end of the sea, with straight fiber segments in alternating south-east, south-west orientations. Initial results reveal clear recordings of local, regional and teleseismic earthquakes, vessel traffic, and near-shore waves. This installation constitutes the longest seismology-dedicated fiber deployment on Earth, deployed in a hypersaline water body, and utilizing the characteristics of salt sedimentation for seismic coupling of the cable.

Seismic and thermal sensing using a deployable DAS fiber in the Sea of Galilee

Ariel Lellouch[1], Shaked Stein[2]

1 Tel Aviv University

2 Israel Oceanographic and Limnological Research

We report a new deployment of a purpose-designed, 13-km long optical fiber in the Sea of Galilee, a freshwater lake within a tectonically active basin along the Dead Sea Fault. The fiber trajectory was designed to cross mapped faults, maximize earthquake detection, location, and focal-mechanism estimation capabilities, and intersect existing temperature monitoring stations. The maximum deployment depth is about 35 m. The ~170 km2 lake is covered by 12 strong-motion monitoring stations, which we use to independently validate our seismological analysis. We will present initial results from earthquake monitoring, fault mapping, and thermal measurements. In addition, we will share some lessons learned from an academic fiber deployment operation. We suggest that, given adequate planning, such deployments are feasible for many academic groups and can significantly improve observational capabilities in traditionally unmonitored areas.

Single array performance in the 2025-04 Marmara sequence

Adam Klinger[1], Andreas Eisermann[1,2], Alon Ziv[1,2]

1 Seismic AI; 2 Tel Aviv University

The Turkey 2025-04 aftershock sequence following a Mw 6.2 mainshock in the Marmara Sea ~100 km from Istanbul, produced a rich seismic catalogue in the following week with two magnitude 5 events within 10 minutes after the mainshock. Whilst Google's android early earthquake warning system provided several seconds of lead time to Istanbul for the mainshock, it performed poorly in both aftershock detection and magnitude estimate. We find that a 4-node small aperture array provides both excellent completeness and real time magnitude and location estimates, outperforming Google's android system and providing more robust and faster association, leading to larger potential lead times to impact, than a conventional regional system where stations are often at least tens of kilometers apart.

Closing the Offshore Gap: Integrating Distributed Acoustic Sensing into Operational EEW Networks

Ran N. Nof[1], Yuancong Gou[2], Richard M Allen[2], Brian Pardini[2], Ivan Henson[2], Angela Lux[2], Weiqiang Zhu[2], Taka'aki Taira[2], Julien Marty[2]

1 The Geological Survey of Israel, 2 Berkeley Seismology Lab, UC Berkeley, CA, USA

Earthquake Early Warning (EEW) systems rely on dense seismic networks to rapidly characterize events, yet their effectiveness is often limited in offshore regions where instrumentation is sparse. Distributed Acoustic Sensing (DAS) offers a novel capability by converting existing subsea fiber-optic cables into dense seismic arrays. We present dEPIC (DAS-Earthquake Point-source Integrated Code), the first operational framework designed to integrate DAS arrays into EEW systems.

Deployed on a submarine cable in Monterey Bay, California, dEPIC utilizes an edge-computing architecture to process high-volume strain rate data in real time. The system employs a GPU-accelerated, machine-learning-based phase picker adapted for DAS, coupled with a grid-search location algorithm and empirical magnitude estimator. To address the azimuthal ambiguity inherent in linear cable geometries, we developed real-time location quality metrics—prominence and distribution scores—that effectively suppress unstable solutions.

Performance evaluations using archived event replays and continuous real-time data demonstrate that dEPIC successfully detects both onshore and offshore events with sub-second processing times. The system operates both autonomously and in coordination with ShakeAlert's EPIC algorithm, improving detection speed for offshore seismicity. Crucially, since the Israeli "Truaa" EEW system employs this same EPIC algorithm, dEPIC offers a straightforward integration pathway to enhance local capabilities. While developed in California, this modular framework is highly adaptable and particularly relevant for the Eastern Mediterranean. Applying dEPIC to existing telecommunications infrastructure could significantly enhance early warning capabilities for offshore hazards, such as those originating from the Cyprian Arc, where traditional station coverage is limited.

A Zero Calibration, Globally Applicable, DAS based Magnitude Estimation Algorithm for Earthquake Early Warning Tested in Pseudo Real Time in California, Chile and Israel

Omry Volk[1], Itzhak Lior[1], Ran Nof[2]

1 - Institute of Earth Sciences, The Hebrew University of Jerusalem. 2 - Geological Survey of Israel

Distributed Acoustic Sensing (DAS) has emerged as a promising technology for Earthquake Early Warning (EEW), particularly for offshore events where additional warning time can substantially reduce risk. Existing DAS-based EEW systems, however, rely on empirically calibrated magnitude estimation methods that require extensive regional and per-channel calibration, creating a significant barrier to deployment in new or data-sparse regions. We present a physics-based magnitude estimation algorithm that eliminates the need for calibration while maintaining competitive performance. The method was evaluated using three diverse DAS datasets from offshore California, offshore central Chile, and onshore central Israel, covering earthquakes of magnitude 2–5. Using identical parameters across all regions, our approach achieved results comparable to calibrated methods, enabling accurate, globally applicable, day-one deployment of DAS-based EEW systems.

A revised catalogue of historical earthquakes in Israel and its surroundings: implications for seismic hazard assessment

Motti Zohar[1], Amos Salamon[2], Rehav (Buni) Rubin[3]

1 University of Haifa, 2 Geological Survey of Israel, 3 Hebrew University of Jerusalem

Historical earthquakes provide a critical basis for understanding long-term seismicity along the Dead Sea Transform and for assessing regional seismic hazard. However, several existing earthquake catalogues for Israel and its surroundings contain duplicated, misinterpreted, or poorly substantiated events, introducing uncertainty into estimates of earthquake recurrence and damage patterns. Here, we present a comprehensive reassessment of historical earthquakes affecting Israel and its surroundings over the past 3,000 years, with particular emphasis on the second millennium CE, for which historical documentation is relatively abundant and reliable.

Earthquakes were systematically evaluated through critical source analysis and resulted in three categories: (1) 71 earthquakes that are considered reliably documented; (2) 41 earthquakes whose occurrence remains uncertain; and (3) 46 earthquakes that were

previously attributed to the region but were found to have occurred and affected elsewhere. The results reveal recurring spatial patterns of earthquake damage along the Dead Sea Transform as well as repeatedly damaged cities. Based on the revised dataset, the average recurrence intervals during the second millennium CE are approximately 45, 55 and 170 years for earthquakes causing any documented damage, highly damaging earthquakes and severely destructive earthquakes, respectively, although occurrence is temporally irregular.

The revised reconstruction provides a robust basis for understanding the long-term seismicity of the southern Levant and indicates that destructive earthquakes have occurred more frequently than so far suggested by the commonly cited recurrence interval of approximately 100 years. The revised catalogue therefore provides an improved foundation for seismic hazard assessment, risk mitigation, and future earthquake preparedness.

Two millennia of earthquake records on the Dead Sea transform and implications for fault displacement hazard analysis

Matty Sharon[1,2], Shmuel Marco[3], Amotz Agnon[1], Robb Moss[4], Amos Salamon[2], Itzhak Lior[1]

1. Hebrew University of Jerusalem

2. Geological Survey of Israel

3. Tel Aviv University

4. California Polytechnic State University

We present results from a ~2 ka synthesis of seismicity along the southern Dead Sea transform (DST), integrating instrumental seismicity from the last ~40 years with historical, archaeological, and paleoseismic evidence. The compilation is used to evaluate the long-term frequency–magnitude distribution of the largest earthquakes and the spatial extent of their ruptures. Our results indicate that earthquakes in the range M 7.0–7.3 are more frequent than expected from extrapolation of the instrumental Gutenberg–Richter relation, whereas earthquakes in the range M ~6.0–6.9 are scarcer than expected from the relation. At the same time, several larger earthquakes indicate rarer $M \geqslant 7.4$ ruptures with possible inter-segment interaction. The resulting pattern does not fit a strict characteristic earthquake model, but neither is it well described by a simple Gutenberg–Richter extrapolation. Instead, the DST record suggests a dominant characteristic size class together with less frequent larger events reflecting structural complexity and occasional barrier crossing. We examine the effect of seismic source characterization on Probabilistic Fault Displacement Hazard Analysis

(PFDHA), comparing the proposed empirically-constrained magnitude distribution with Characteristic and Gutenberg-Richter models, based on several on- and off- fault hazard curves.

Revisiting the 1114/5 CE earthquake sequence in southern Turkey using the February 2023 doublet

Motti Zohar, Jefferson Williams

University of Haifa

This study re-evaluates the historical earthquake sequence that struck southern Turkey in 1114/5 CE as one of the most damaging sequences in the region during the last millennium. We use the February 2023 Turkey doublet as a modern analogue to shed light on the spatial and temporal dynamics of this 12th-century sequence. By applying geospatial analysis to Intensity Data Points (IDPs) derived from historical sources, we identify persistent damage hotspots associated with the 1114/5 sequence in the Kahramanmaraş–Elbistan and Antakya regions. This damage pattern aligns closely with the 2023 rupture zones, suggesting a repeated scenario of similar fault segments nearly 900 years apart. A rich historical record, including two eyewitness accounts at different endpoints of the fault rupture, is combined with paleoseismic evidence and insights from the February 2023 doublet to propose that the 1114/5 events involved a branch fault rupturing resulting in multiple large-magnitude earthquakes triggered in close succession. This study presents a "reverse approach" differing from traditional historical seismology by using patterns of modern seismicity to constrain pre-instrumental earthquake events. The implications reinforce the East Anatolian Fault Zone's (EAFZ) capacity for cascading, high-magnitude ruptures, providing crucial insights for understanding the seismic history and hazard assessment of the region and the broader Eastern Mediterranean.

Posters

Breakdown of the classical rupture theory and earthquake propagation in the “forbidden” super-Rayleigh range

Anna Pomyalov, Eran Bouchbinder

Weizmann Institute of Science

Earthquakes propagating faster than the shear wave-speed are commonly thought to undergo a super-shear transition upon which they discontinuously jump from the sub-Rayleigh regime to the super-shear one. The super-Rayleigh regime, i.e., the range of propagation speeds between the Rayleigh and shear wave-speeds, is regarded as “forbidden” by the two-dimensional classical rupture theory.

We revisit the assumptions underlying the classical theory and develop a rupture theory that takes into account the dependence of the fault strength (frictional resistance) on the slip rate. The theory quantitatively agrees with numerical simulations nearly up to the Rayleigh wave-speed. Yet, very close to the latter, two-dimensional rupture solutions change their character due to frictional rate nonlinearity and rupture continuously propagates through the “forbidden” super-Rayleigh range into the super-shear regime, without a sharp super-shear transition.

These results demonstrate that frictional rate dependence, generically observed in experiments, can have profound implications for fast earthquake propagation.

Conjugate fault segmentation and swarm mechanics along the shallow western margin of the Kinneret basin, Sea of Galilee

Aleksei Nelaev, Eyal Shimony, Ariel Lellouch

Department of Geophysics, Tel Aviv University

This study evaluates the structural architecture and mechanical evolution of the northern Kinneret basin using a new catalog (N=1,244) and ensemble kinematic analysis of 65 focal mechanisms. The catalog resolves a sharp lateral contrast in hypocentral depth at 35.58 deg. E. Background seismicity extends to 15 km depth along the eastern margin and aligns more closely with the mapped East Marginal Fault (EMF) than with the Diagonal Fault (DF). A relative seismicity gap is observed near the DF trace, separating deeper eastern-margin seismicity from the shallow western swarm activity. In contrast, 2018 swarm activity clusters

at depths <6 km along the western Kinneret fault system. Ensemble analysis of 65 focal mechanisms yields a dominant slip-plane strike of 180.1 deg. with 75.5 deg. eastward dip. However, three-dimensional robust L1-norm optimization of hypocentral distributions reveals an underlying segmented macro-architecture, resolving a steeply dipping Northern Branch striking 20.6 deg. (dip 69.9 deg.) and a Southern Branch striking 332.0 deg. (dip 67.4 deg.), forming an intersecting segmented network. The 4–6 day delayed activation of the southern cluster (32.86 deg. N) is consistent with a discontinuous fault model. High-resolution 3D static stress modeling indicates that the mainshock on Day 0 elastically transferred a substantial positive stress load (up to +4 MPa Coulomb Failure Stress) onto the adjacent southern segment. Fluid-driven pore-pressure diffusion subsequently may have acted as the temporal regulator governing the 4–6 day delay to failure. The shallow swarm activity is temporally coincident with the onset of geodetically observed creep (2.6 ± 0.3 mm/yr) along the northern Jordan Valley segment. This co-occurrence suggests a possible mechanical link between the 2018 sequence and the locked-to-creeping transition along the Dead Sea Transform.

Analysis of 2018 Lake Kinneret Earthquake Sequence

Ori Stauber, Asaf Inbal

Tel Aviv University

The Kinneret Basin has hosted several vigorous earthquake sequences in recent years and is considered one of the most seismically active segments of the Dead Sea Transform. Owing to its dense seismic instrumentation, the Kinneret basin provides a unique natural laboratory for studying earthquake source processes. In July 2018, two moderate (M>4) earthquakes struck that area and were followed by an aftershock sequence lasting approximately one month. Shortly before this sequence, the Israeli Geological Survey deployed strong-motion accelerometers around the shores of Lake Kinneret, providing excellent azimuthal coverage at short epicentral distances. Here, we utilize the 2018 dataset to study the rupture histories of the two M>4 earthquakes. Our analysis employs the Empirical Green's Function (EGF) deconvolution method, in which small, co-located aftershocks serve as empirical Green's functions. Deconvolution effectively removes path and site effects, yielding relative source-time functions that isolate the source process. We use these relative source-time functions to reconstruct the rupture time histories of the July 2018 M > 4 earthquakes and discuss their implications for the 2018 aftershock sequence.

Ground Motions Variability as a Function of Seismic Source Characterization- a Numerical Study

Amany Abou Assa[1], Ronnie Kamai[2], Michael Tsesarsky[1,2]

1. Dept. of Earth and Enviromental Science , Ben-Gurion University of the Negev

2. Dept. of Civil and Environmental Engineering Ben-Gurion University of the Negev

Israel exhibits pronounced geological complexity along the Dead Sea Fault System, spanning from ancient crystalline basement and stiff carbonates to soft basin sediments and basalt, creating strong bi-material impedance contrasts and complex velocity structures over short distances. Due to a sparse instrumental catalog lacking strong-motion recordings, 3D physics-based numerical simulations can serve as a key component in improving seismic hazard evaluations.

This study investigates how modeling choices of kinematic source parameters; particularly rupture velocity and fault-zone velocity structure, affect the amplitude, distribution, and spatial variability of ground motions. Using the SW4 finite-difference code and rupture models generated by the Graves & Pitarka (2010) methodology, we conducted a suite of controlled 3D simulations across two main configurations: Laterally Homogeneous Host Rock (LHH) and a Bi-material Interface (BMI) system. In LHH models, varying fault-zone stiffness under identical seismic moments revealed that average stiffness governs slip and ground-motion amplitudes, with lower stiffness yielding larger slip and stronger amplitudes. In BMI scenarios, testing different fault-to-interface distances showed that while the fault's exact position has minor influence on the overall amplitude pattern, significant amplification consistently occurs on the soft side due to energy reflection and impedance contrast.

Overall, the choice of rupture velocity model plays a key role in the resulting ground motions. Accurately defining the rupture velocity relative to the local shear-wave velocity is therefore essential for achieving realistic earthquake modeling and enhancing the reliability of seismic hazard assessments

Upgrading the real-time seismic processing: obtaining an improved automatic earthquake catalogue

Lewis Schardong, Andrey Polozov, Hila Navon, Marina Gorstein, Nadav Wetzler, Ran Novitsky Nof, Ittai Kurzon

Geological Survey of Israel

At the end of 2022, the Geological Survey of Israel's Seismological Division started upgrading its real-time processing and detection capabilities by implementing gempa's SeisComP software package into its systems. This transition was finalised in January 2024, when a first version of the real-time automatic earthquake detection algorithm was integrated into the production workflow. This initial implementation allowed us to reach a magnitude of completeness (magnitude above which all earthquakes are detected) of M2.2 and to significantly decrease the rate of false events. In this new version, we first improved waveform processing and phase-picking, but most importantly adapted SeisComP's local earthquake monitoring module scanloc to optimise event detection in our region. The parameter exploration for the fine-tuning of the scanloc module started with values recommended by gempa, while some values were further adjusted to reflect our local conditions (faults/network geometry, data quality, etc.). We present the resulting configuration parameters and compare them to the initial implementation. We illustrate the general improvement by producing new detection sets to be compared to our official, manually-picked event catalogue. We show the results of archived-data simulations (playbacks) for the period of August 2024, as well as the results of real-time event detection collected over the course of June 2026. We reach an overall 75% reduction in false events in both data sets, and an addition of ~150 new events (in majority explosions), undetected using the currently in-use configuration.

Adaptive Window-Based Declustering and Temporal Correlation Analysis in Earthquake Catalogues

Mahidip Deb, Yosef Ashkenazy

Ben Gurion University

Seismic catalogs frequently contain clustered sequences in which a mainshock is followed by aftershocks that persist over varying spatial and temporal scales. Reliably separating these dependent events from independent background seismicity a process known as declustering, is essential for statistical seismicity modelling, seismic hazard assessment, and earthquake statistical forecasting. However, most existing declustering methods rely on assumptions and empirical parameters derived from established seismic laws, which may not generalize well across tectonic regions or catalog sizes.

We present a data-driven declustering method that makes no a priori assumptions about the functional form of aftershock decay or its parameters. The method adaptively estimates space-time aftershock ranges from local seismicity rates and employs iterative refinement to converge on a robust estimate of the background rate.

Applying this method alongside conventional declustering approaches, we find that the resulting background seismicity exhibits long-range temporal correlations a result that challenges the classical assumption of a temporally homogeneous (Poissonian) background process. We argue that accounting for these correlations may be necessary to improve the realism and predictive skill of models such as the Epidemic-Type Aftershock Sequence (ETAS) model, which typically assumes a time-independent background rate. By providing more accurate background rate estimation, our approach offers a step toward more reliable operational earthquake forecasting and long-term seismic risk assessment.

Seismic Monitoring of Blind Mole Rats

Yana Novomodsky, Omer Darel, Shay Rotics, Ariel Lellouch

Department of Geophysics, Faculty of Exact Sciences, and School of Zoology, Faculty of Life Sciences, Tel Aviv University, Tel Aviv, Israel

The obligate subterranean lifestyle of the blind mole rat (Spalax ehrenbergi) presents a profound methodological challenge for zoological research, as the overlying soil layer acts as a physical barrier that renders traditional visual monitoring techniques ineffective. While radio-telemetry provides macro-scale spatial mapping, it lacks the temporal and mechanical resolution required to differentiate fine-scale behavioral dynamics. To resolve this limitation, this research exploits the soil as an elastic medium that propagates seismic data generated by the animals during rhythmic "head drumming" communication and body-wave spatial orientation. This study utilizes a continuous, large-scale field deployment of a 168-geophone array in a natural mole rat habitat to capture micro-seismic signatures of underground biological activity. The raw data is processed through advanced spatio-temporal filtering algorithms designed to isolate localized subterranean signals from broad-scale environmental and anthropomorphic surface noise. From this filtered dataset, a high-quality ground-truth database of verified events is constructed to train a specialized Artificial Intelligence (AI) model, optimizing the automated detection of faint or complex signals across the entire corpus. Ultimately, this research aims to characterize the distinct spectral and physical properties of subterranean ground motion, establishing a robust framework to differentiate communicative signaling from mechanical soil excavation. By validating these seismic classifications with complementary sensor collars and surface cameras, this study provides a non-invasive, high-resolution methodology for mapping the behavioral, spatial, and social dynamics of cryptic wildlife populations.

Machine Learning Integration with Geological-Geophysical Data for Blind Fault Characterization in Israel

Aaron Kahn, Alexandra Chudnovsky, Lev Eppelbaum

Tel Aviv University Department of Geophysics

Characterizing active, deep-seated blind faults in tectonically complex and rapidly urbanizing regions remains a critical challenge due to the presence of anthropogenic features, burial, and superficial topographic anomalies. This study presents a robust, multi-data fusion framework that integrates machine learning (ML)-driven optical lineament extraction with the historical seismic evaluations and deep geophysical parameters across Israel. The lineaments' features detected from the Sentinel-2 imagery using automated ML pipelines were systematically filtered to eliminate superficial topographic and infrastructural artifacts. This was achieved by constructing programmatic masks derived from the high-resolution Digital Elevation Model (DEM) topographic position indices, hydrological stream networks, and OpenStreetMap transportation vectors. To separate surficial geomorphic variations from true seismogenic structures, the cleaned lineament network was spatially correlated with historical seismic publications and partitioned by the hypocentral depths. This structural framework was then integrated with historical surface fault maps, gravity anomaly maps, and spatial geothermal gradient anomalies. The synthesis of these subsurface datasets revealed a high-resolution, co-registered structural footprint, highlighting the hidden stress-transfer zones where elevated geothermal fluxes and deep-seated gravity gradients align with the active micro-seismicity.

Void detection using refracted-wave diffractions recorded by Distributed Acoustic Sensing (DAS)

Tzofia Bem, Ariel Lellouch

Department of Geophysics, Faculty of Exact Sciences, Tel Aviv University, Israel

Detection of subsurface undocumented and clandestine tunnels is an important challenge due to their potential impact on infrastructure, public safety, and national security. Conventional seismic imaging methods often struggle to identify such targets because

diffraction signals generated by small underground voids are usually weak and can be masked by others seismic waves and surface noise levels. In this study, we investigate the use of void-induced refracted-wave diffractions recorded by Distributed Acoustic Sensing (DAS) for void detection and location estimation, using an automated workflow. This approach uses distant sources to create temporal separation between the diffracted wavefield and subsequent phases, facilitating its analysis. We evaluate its robustness, accuracy, and reliability of the proposed method using a large set of 3D wave equations simulations. Finally, we validate the method using field DAS data acquired in a complex near-surface environment.

<u>Distributed Acoustic Sensing Interferometry with highway traffic noise sources</u>

Jonathan Levy, Ariel Lellouch

Tel Aviv University

Distributed Acoustic Sensing (DAS) enables continuous, high-resolution recording of seismic signals along fiber optic cables, making it well suited for ambient-noise interferometry at scales of hundreds of meters to kilometers. Standard interferometric retrieval assumes that noise sources are isotropically distributed and far from the array.

However, this assumption does not always hold; DAS arrays near highways are dominated by directional traffic loading parallel to the array with a constant offset. We investigate the effect of noise source distribution constrained to a line parallel to the DAS array. We derive a closed-form expression for the cross-correlation of inline DAS channels excited by a parallel line of moving traffic sources by integrating surface-wave Green's functions along the source line and evaluating the result asymptotically.

We then simulate Virtual Source Gathers and dispersion images via the Frequency-Bessel Transform for varying velocity models and geometric layouts, comparing them to the asymptotic solution and theoretical phase velocities. We find that the retrieved Rayleigh-wave phase velocity is systematically biased above its true value by a secant-like geometric factor predicted by the asymptotic analysis. From the simulations we calibrate a correction factor that depends on array length, road length, and wavenumber. We further show that this configuration can produce Love-wave arrivals in the virtual source gather. These findings provide both a correction for the bias in apparent phase velocity and a prediction for the Love-wave signal - typically absent in inline DAS interferometry.