Large-Scale Community Partnerships (LSCP) Proposal Renewal (Sept 2024 - August 2025)

SCEC Earthquake Modeling, Ground Motion, and Hazard Simulations (FTA-SCEC)

1. Introduction

Our SCEC research community is requesting a renewal allocation on Frontera for the period September 1, 2024 to August 31, 2025. Access to Frontera will enable our Statewide California Earthquake Center (SCEC) team to perform large-scale, broad impact, seismic hazard research calculations which are only possible with high-performance computing (HPC) capabilities, such as those provided by Frontera. In September 2023, after 30 years of operation as the Southern California Earthquake Center, SCEC began operations as the Statewide California Earthquake Center, funded by new NSF and USGS awards which extend our earthquake system science research program to include the full geographic region of California. This extension of SCEC's geographical region of interest promotes statewide research and hazard initiatives. SCEC conducts and coordinates fundamental and applied research on earthquakes using California as its main natural laboratory. SCEC's research program relies on strong collaboration among researchers, and supports research and education in seismology, tectonic geodesy, earthquake geology, and computational science. SCEC integrates science results into computational tools to support seismic hazard improvements. Our seismic hazard research aims to increase the accuracy of earthquake ground motion simulations and seismic hazard analysis, reduce uncertainties in current seismic hazards estimates, and broaden the usefulness of seismic simulation software tools for engineering and preparedness applications. These objectives are only obtainable through strong collaborative teamwork and require Frontera-enabled HPC capabilities. We will use our awarded LSCP allocation to meet the needs of the large SCEC community of earthquake system science researchers.

2. SCEC LSCP 2023-2024 Allocation Progress Report

Allocation usage. As of June 15th, 2024 when we submit our renewal, we will have completed about 80% of the award duration and we have used 28% of the 600,000 SUs we received for Sept 1 2023 - Aug 31, 2024. We are prepared to make significant use of our remaining allocation in the next two months.

Underutilization of Allocation: Our research group has underutilized our allocation so far this year but under usage of our allocation awards is not typical for our group. For example, our SCEC collaboration used 100% of our 2021-22 and 2022-23 LSCP allocations. To help us avoid possible reductions in our LSCP allocation renewal this year, which can lead to delays for our group including grad students and postdocs, we'd like to describe a number of factors that have contributed to current usage. One reason for our current lagging burn rate is that we have not started to perform the seismogram synthesis portion of a northern California CyberShake hazard model calculation. We do plan to conduct this large production run before the end of our current LSCP allocation in August 2024. We also planned a full-system run (on Texascale Days) high frequency deterministic wave propagation simulation with non-linear response which would require significant usage, but have not been able to schedule this large run with all our required team members. This has been a transition year for SCEC as many of the staff and research community have been involved in the transition from the Southern California Earthquake Center to the Statewide California Earthquake Center. SCEC received new awards from both the NSF and USGS in Sept 2023 which has initiated significant activities organizing the center to deliver on our statewide research goals. The center's leadership has spent a significant amount of time planning and prioritizing the new center's work. While planning activities for the new Statewide California Earthquake Center impacted the rate at which we performed our computational research, priorities for the new center are now established and the research proposed in this allocation request reflects those updated priorities. We note that also two new, scalable codes/applications are being added in this request that achieve high performance on Frontera.

Current Usage:

So far, our Frontera usage this allocation year has supported a combination of small-scale tests and simulations, followed by several large-scale simulations which required significant science-based developments prior to initiation. The main codes used on Frontera during the 2023-2024 LSCP allocation were RSQSim [9] and 3D-EWP [13]. We used our Frontera LSCP allocation to make progress on the following computational milestones:

M1. RSQSim Earthquake Simulations.

This past year we used simulations on Frontera to make important progress on long period ground motions. This work was recently submitted for publication [Shaw, Milner, and Goulet, submitted, 2024] "Deterministic physics-based earthquake sequence simulators match empirical ground motion models and enable extrapolation to data poor regimes: Application to multi-fault multi-mechanism ruptures". In this paper, we use the deterministic earthquake simulator RSQSim to generate complex sequences of ruptures on fault systems used for hazard assessment. We show that the source motions combined with a wave-propagation code create surface ground motions that fall within the range of epistemic uncertainties for the NGA-West2 set of empirical ground motion models used in the USGS 2023 National Seismic Hazard Model. We show the simulator model ground motions are well calibrated where there are good data constraints, and have good correspondence in regions with fewer data constraints. We show magnitude, distance, and mechanism dependence all arising naturally from the same underlying friction. The deterministic physics-based approach provides an opportunity for better understanding the physical origins of ground motions. Having shown the model is credible, we apply it to a problem where observations are lacking. We examine the case of crustal faults above a shallow subduction interface seen to break co-seismically in simulations of the New Zealand fault system. These types of events were left out of consideration in the most recent New Zealand national seismic hazard model due to the modeling complexity and lack of observational data to constrain ground motion models. Here, we show that in the simulator, by breaking up the coseismic crustal and interface rupturing fault motions into two separate subevents, and then recombining the resulting ground motion measures in an incoherent manner, we reproduce well the ground motion measures from the full event rupture. This provides a new method for extrapolating ground motion models to more complex multi-fault ruptures.

M2. Ground Motion Modeling for Path Effects.

This past year we have made progress on two tasks under this milestone. The first task continues our investigation into how source and path effects for large magnitude events can be represented in non-ergodic Ground Motion Models (GMMs). We added 10 large magnitude events to our simulated dataset of over 1100 hypothetical earthquakes (magnitudes 4-7) computed in both 1D and 3D seismic velocity models, and for sites covering a large range of rupture distances and azimuths. From this dataset, we compare mean path effects among groups of events with different magnitudes and examine dependence on distance and azimuth using various approaches to quantify the effective distance to the fault. Our findings indicate that it is difficult to satisfactorily approximate the path effects of larger events with that of smaller events using these approaches. This finding complicates our ultimate goal of developing guidelines for how large magnitude ruptures can be adequately represented within non-ergodic GMMs. The second task investigates the potential impacts of an earthquake "doublet" occurring on the Hayward and Calaveras faults in the San Francisco Bay region, which is motivated by the devastating February 2023 earthquake doublet in Türkiye, where a large magnitude event was followed roughly 9 hours later by another large event on an adjacent fault. We compute broadband motions using a combination of deterministic and stochastic approaches for the lower- and higher-frequency components, respectively. Our deterministic calculations use 3D-EWP and the USGS 3D San Francisco Bay region velocity model with a minimum shear velocity of 400 m/s and grid spacing of 80 meters. The computational domain is 300 km x 240 km x 90 km and requires nearly 13 x 10^9 mesh points. **Fig.1** shows snapshots of the propagating wavefield for the two earthquake scenarios. Waveforms are saved on a 1.2 km by 1.2 km grid of points and used to produce scenario ShakeMaps. Currently we are analyzing potential impacts on the built environment using the simulated ground motions. Additionally, we save ground acceleration time histories at other sites corresponding to locations of mid- and high-rise buildings for later use in structural response analysis.

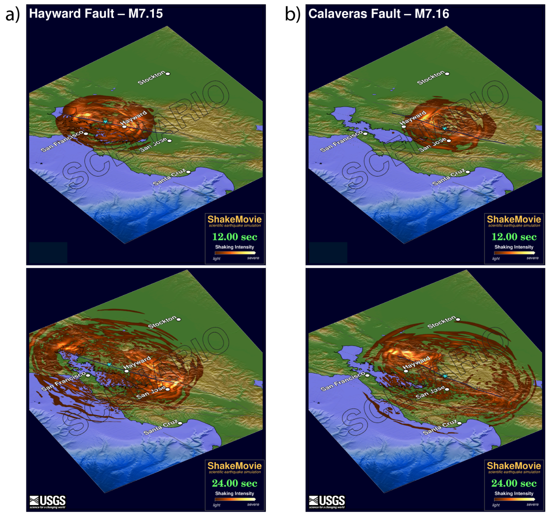

Fig. 1: Snapshots of wavefield propagation for the a) Hayward and b) Calaveras simulations at times of 12 sec (top) and 24 sec (bottom) after rupture origin. The blue star and black line denote the epicenter and fault trace, respectively, for each simulation. The simulations show strong rupture directivity effects along the fault strike as well as strong channeling of energy in the basin sediments. These features are hard to quantify directly using empirical GMMs.

M4. Nonlinear Dynamic Rupture Simulations.

Built on our Texascale Days run [24], we have this year refined the velocity model and have sources ready for a renewal 4-Hz dynamic rupture simulation that combines spontaneous rupture and propagation simulations in a single step. The checkpointing capability has been added to our CPU-version of Iwan AWP-ODC code which allows simulation restart. We will next verify the correctness of the restarted results and perform an exercise at large scale - at least half of Frontera, which might challenge Frontera in handling metadata and require additional system level support.

M5. Broadband CyberShake Simulations.

This year to date we have made progress towards our milestone of a Broadband CyberShake study for Northern California. We have performed code verification of our deterministic low-frequency and stochastic broadband codes and are validating our results using historic earthquakes. We anticipate beginning our large-scale study for hundreds of sites in Northern California shortly.

3. New Publications Related to our Frontera Research

- Baker, J.W., S Rezaeian, CA Goulet, N Luco, G Teng (2022) A subset of CyberShake ground-motion time series for response-history analysis, Earthquake Spectra 37 (2), 1162-1176
- Shaw, B. E. (2023). Magnitude and slip scaling relations for fault based seismic hazard, Bull. Seismol. Soc. Am.,doi: 10.1785/0120220144
- Meng, X., R. Graves, C. Goulet, G. Parker (2024). Constraining Large Magnitude Event Source and Path Effects Using Ground Motion Simulations, Proc. 18 World Conf. Eq. Eng., Milan, IT.
- R. Graves, J. Wang-Connelly, E. M. Thompson, V. Quitoriano, D. Wald, K. Milner, S. Gunay (2024). Broadband Ground Motion Simulations for a Türkiye-like Earthquake "Doublet" on the Hayward and Calaveras Faults, SSA 2024 Annual Meeting Abstract, Seism. Res. Lett., 95, 1202.
- Shaw, B.E., K.R. Milner, C.A. Goulet. Deterministic physics-based earthquake sequence simulators match empirical ground motion models and enable extrapolation to data poor regimes: Application to multi-fault multi-mechanism ruptures, Submitted, 2024.
- Callaghan, S., and the CyberShake Collaboration (2024). Updates on CyberShake in Northern California. U.S. Geological Survey Northern California Hazards Workshop, January 30, 2024.
- Rojas, O., Monterrubio-Velasco, M., Rodriguez, J. E., Callaghan, S., Abril, C., Holldorson, B., ... & de la Puente, J. (2024). CyberShake Earthquake Fault Rupture Modeling and Ground Motion Simulations for the Southwest Iceland Transform Zone. arXiv preprint, arXiv:2404.01533.

4. Research Objectives and Plans

In this LSCP allocation renewal request for the time period of Sept 2024 - Aug 2025, we are requesting access to TACC computing resources so the SCEC community can perform computational research that will increase the accuracy of earthquake, ground motion, and hazard simulations and broaden the usefulness of seismic simulation software tools for engineering and preparedness applications. We will continue our computational research on earthquake catalog simulation (RSQSim), fault dynamics (SORD, Waveqlab3D), and 3D ground motion simulations (3D-EWP, AWP-ODC). In addition, we will use the CyberShake components ported to Frontera to perform workflow-based probabilistic seismic hazard analysis at higher seismic frequencies. This research will be done using computational codes we have used previously on Frontera including AWP-ODC, 3D-EWP, CyberShake [6][17][38], Waveqlab3D, and RSQSim. We plan to add the community dynamic rupture code SeisSol [40][41] and the seismic cycle code Tandem [40], which have been run previously with good scaling on Frontera and other systems.

A high priority for our research group is to establish that we are working to realize the potential of our new statewide research. Researchers and stakeholders would like to apply consistent methods for performing seismic hazard computational methods in both southern and northern California. As a result we have defined our research objectives as a process of assembling, assessing, and improving the essential components used in modern seismic hazard modeling, and then integrating the improved components into a probabilistic seismic hazard analysis (PSHA) model which represents the essential interface between seismic hazard and risk communities. Our proposed research objectives are designed to assemble the essential components needed to perform modern physics-based seismic hazard calculations across the full state of California using consistent models and methods. We will use the existing models and methods, and improve on them, in order to progress on both computational and research grand challenges related to seismic hazard mitigation. We have structured our computational research plan with three objectives (Table 1), which are described in the following sections. The following sections provide a brief description of the computational research activities that we use to pursue these objectives.

Table 1. SCEC 2025 Computational Research Objectives

Objective 1: Develop physics-based multi-cycle dynamic rupture models capable of informing California earthquake rates.
Objective 2: Develop earthquake wave propagation models that accurately model high frequency and large amplitude ground motions.
Objective 3: Integrate best available fault models, velocity models, rupture models, and wave propagation methods into probabilistic seismic hazard models for California.

Objective 1: Develop physics-based multi-cycle dynamic rupture models capable of informing California earthquake rates. Dynamic rupture models seek to model the complex physics involved in fault ruptures across a wide range of physical scales from grain sizes in rocks to faults that extend hundreds of kilometers. We are developing multi-cycle earthquake simulators that model the stress transfer between faults leading to long term fault system rupture models which can inform about earthquake rates required in earthquake rupture forecasts.

Objective 2: Develop earthquake wave propagation models that accurately model high frequency and large amplitude ground motions.

Earthquake wave propagation models simulate the passage of seismic waves through the earth. Our research focuses on seismic hazards, so we seek to accurately model large ground motions capable of generating damage. We are developing simulation methods that can simulate ground motions at frequencies above 1 Hz accurately and efficiently, and developing methods to accurately model both near-fault non-linear motions and site-specific non-linear response to strong ground motions.

Objective 3: Integrate best available fault models, velocity models, rupture models, and wave propagation methods into probabilistic seismic hazard models for California.

SCEC's seismic hazard research is an iterative process of development, implementation, evaluation, and improvement. Probabilistic seismic hazard information is an essential interface between geoscientists and civil engineers, and because PSHA is used in broad impact applications such as building codes and emergency response planning, our research is leading development of next generation PSHA models.Our research improves PSHA model components, and then integrated the improvements into the established CyberShake computational system. This integration activity is the essential work required to deliver research advances into broad impact applications.

5. Resource Usage Plans and Justification

We have compiled our allocation request in **Table 1**, for which we define computational milestones per topic and code, for practical purposes. The section below summarizes the codes and our computational plans and justifications for the requested SUs for each milestone, based on our experience to date with each code on Frontera. Benchmark performance has been submitted in our previous LSCP allocation requests for several of our previously used codes. We provide software performance measurements on Frontera for our remaining codes in **Figure 3** and **Figure 4** below.

Table 1: SCEC LSCP Allocation Request for September 2024 - August 2025

Lead	Milestone	Simulation Description	Software	# Sims	SUs/ Sim	Number of Sims x NH	Frontera SUs (node-hrs)	Temporary storage (TB)	Project disk storage (TB)
Withers	M1	Complex Dynamic Rup	Waveqlab3D	100	(320 nodes x 6 hours) = 1920 NH	(100 x 1920) = 200000	200,000	5	2
Gabriel	M2	Delayed dynamic rupture	Tandem	20 high-res 2D; 3 high-res	2D: 550 nodes x 5 hours = 2750 NH; 3D: 2000 nodes x	120,000	120,000	10	1
Shaw	M3	ERF development with rate and state	RSQSim	100 lo-res; 20 hi-res	(64 nodes x 12.5 hr = 800 NH); (128 nodes x 47 hr) = 6000 NH	(100 x 800) + (20 x 6000) = 200000	200,000	10	1
Pinilla-Ramos	M4	Variability in dynamic rupture simulations	SeisSol	12 configs x 5 stresses = 60	(200 nodes x 10 hrs) = 2000 NH	(60 x 2000) = 120,000	120,000	10	1
Gabriel	M5	UQ of Fault Zones response	SeisSol	100 MLDA Sims; 10 lo-res; 4 med res; 1 hi-res	900 NH; 1000 NH; 500 NH; 2000 NH	(100 x 900) + (2 x (10 x 100) + (4 x 500) + (1 x 2000))) =100000	100,000	20	5
Graves	M6	Source and Path Validation	3D-EWP	300 low-res; 50 hi-res	(300 nodes x 1.333 hr = 400 NH); (300 nodes x 4 hr = 1200 NH);	(300 x 400) + (50 x 1200) = 180000	180,000	15	2
Callaghan	M7	CyberShake 2Hz sites post-processing calculations	CyberShake	25	(400 nodes x 5 hrs= 2000 NH)	(25 x 2000) = 50000	50,000	50	5
					Total		**970,000**	**120**	**17**

M1: Dynamic Rupture Earthquake Source Generation - We will use the Waveqlab3d dynamic rupture software to simulate seismic events along complex-geometry faults and continue to develop a diverse earthquake source database. We use a spontaneous earthquake ruptures generation method with stochastic fault roughness that creates realistic broadband energy in the resulting ground motions. This year we will focus on generating simulations that investigate the effect of the dip angle of faulting, geometry of the fault, and free-surface topography on both the rupture propagation and resulting ground motions. We plan to run a total of 100 production runs that resolve frequencies up to 5 Hz (varying with velocity model constraints), to capture epistemic uncertainty in the model parameterization. An example simulation for a Mw 7 vertical dipping fault uses 320 nodes for ~6 hours, to ensure the calculation of seismic wave-propagation extends to the furthest regions of the domain, totalling ~1920 SU's per rupture.

M2: Delayed dynamic triggering and complexity of the seismic cycle on heterogeneous, rough strike-slip faults: the Ridgecrest, CA, sequence- Using the volumetric seismic cycle and aseismic slip code Tandem [40], we will perform quasi-dynamic seismic cycle simulations on 2D and 3D strike-slip faults governed by rate-and-state friction. We incorporate self-affine heterogeneities to initial stress and strength and fault roughness to investigate complex earthquake sequences and earthquake dynamic triggering, which often exhibits a time delay with respect to the largest stress perturbation[42]. Tandem is an open-source discontinuous Galerkin volumetric solver that utilizes the PETSc-TAO library and achieved excellent strong- and weak-scaling up to 112,000 MPI-ranks on Frontera. We plan to conduct 20 high-resolution (1 km on-fault element size, 137k element mesh size) 2D simulations, each requiring 150,000 core hours for ~10,000 year-long simulation (25 million time steps), which is ~2750 node hours in Frontera, at a total of 55k node hours. Our equivalent 3D simulations will require a large mesh size of ~50 Mio. elements and ~21,500 node hours per simulation at a total of ~65k node hours.

M3: Earthquake Rupture Forecast sets and Ground Motions from deterministic earthquake simulator - The deterministic earthquake rupture simulator RSQSim generates long sequences of complex ruptures on fault systems at time and length scales relevant to seismic hazard. We aim to further study these sequences, and the ground motions that arise from the complex source motions, including comparisons against statistical hazard models such as the USGS 2023 National Seismic Hazard Map, and against empirical ground motions models such as the NGA-West2 relations used in these hazard maps. We aim to study additional features impacting rupture nucleation centers and associated directivity measures. To accomplish these goals, we estimate 100 sensitivity runs at 800 node-hours per run, along with 20 higher resolution runs at 6000 node-hours per run, for a request of 200,000 SUs.

M4: Assessment of the variability induced by dynamic rupture modeling - We will perform rupture dynamic simulations using the code SeisSol to sample the key parameters involved in dynamic source characterization to compare the obtained outputs with near-field recorded waveforms (to diminish wave propagation effects) and ground-motion models. This study will simulate earthquakes in pulse-like propagation regime, thus modeling large-magnitude earthquakes in crustal tectonic environments (M>7.0) and evaluating a broad-band frequency radiation up to 5 Hz. We will adopt 12 different configurations of the inputs controlling dynamic crack propagation, each one sampling five different stress configurations prior to the rupture. Each simulation requires 2,000 node hours, totaling 120,000 node hours for the development of this study.

M5: Uncertainty quantification of the nonlinear rock parameters from earthquake observations based on dynamic rupture and wave propagation simulation - We will use SeisSol to employ a Multi-level (or Multi-index) Delayed Acceptance (MLDA) Markov chain Monte Carlo algorithm [43] and physics-based 3D earthquake forward modeling with Drucker-Prager plasticity or nonlinear damage rock models [44]. We will investigate the uncertainties in the off-fault nonlinear parameters constrained by strong motion seismometers, GPS and geodetic data during the Ridgecrest, CA, earthquake sequence. SeisSol is currently supported as one of the characteristic science applications (CSA) in NSF's LCCF program in collaboration with TACC, and we benchmarked this setup on Frontera during several Texascale days. On CPU machines, SeisSol employs an MPI+OpenMP+Pthread scheme, parallelizing across the mesh cells with OpenMP. Pthread is used for overlapping communication and I/O with computation. To simulate 20 samples on the finest level of MLDA, 40 samples on the coarser level, and 600 samples on the coarsest level, we need around 1,800 node-hours. To get 1,000, 2,000, and 30,000 samples on the three MLDA levels to assess uncertainties in the plastic coefficients requires 1,800 x 1,000 / 20 = 90,000 node-hours. We will also implement and test a numerical Green's function approach to speed up inversions in elastic materials. To do this, we will need to test different resolutions, model geometries, and receiver configurations. We plan to run 10 low-resolution, 4 medium-resolution, and 1 high-resolution models per geometry, which cost 10 x 100, 4 x 500, and 1 x 2,000 node-hours, respectively, for two geometries, costs 10,000 node-hours, or a total of 100,000 SUs for this milestone.

M6: Source and Path Validation using Moderate Magnitude Earthquakes - Using 3D ground motion simulations, we will model waveforms recorded for moderate magnitude (M4-5) earthquakes in both southern and northern California in order to better constrain finite-fault source properties of these events as well as investigate the upper frequency limit at which existing 3D seismic velocity models can adequately match observed waveform characteristics. The target bandwidth is frequencies of 1 Hz and greater while also incorporating minimum shear wave velocities (Vs) down to 300 m/s. We will use simulations of near-source observations to explore ranges of magnitude-area and rupture speed scaling for these events with the goal of developing updated scaling relations for these properties. Running one lower-resolution simulation for 200 sec of time requires about 400 node-hours on Frontera. One higher-resolution simulation for the same duration of wave propagation time requires about 1200 node-hours. We plan to examine six source variations for each of 50 earthquakes using the lower-resolution domain (300 simulations), and then we will run each earthquake using its best constrained source in the higher-resolution domain (50 simulations). For this work, we are requesting a total of 180,000 SUs (300 x 400 SU + 50 x 1200 SU).

M7: CyberShake 2 Hz deterministic PSHA - We will investigate the impact of 2 Hz deterministic simulations on CyberShake hazard models. For 25 selected northern California sites with existing 1 Hz CyberShake hazard results, we will calculate 2 Hz deterministic results and compare these with previously computed 1 Hz CyberShake hazard results to determine the impact of higher frequency deterministic simulations on hazard estimates. We plan to perform 25 deterministic 2 Hz seismogram synthesis simulations, using Strain Green Tensors which will be calculated using a GPU code on OLCF Frontier. For this milestone, we are requesting a total of 50,000 SUs (25 simulations x 400 nodes x 5 hrs/simulation).

***Code and Performance.* :** We present performance measurements for our proposed research codes on Frontera in the following figures with measurements for Waveqlab3D and SeisSol (**Figure 3**),3D-EWP and RSQSim (**Figure 4**), and Tandem (**Figure 5**).

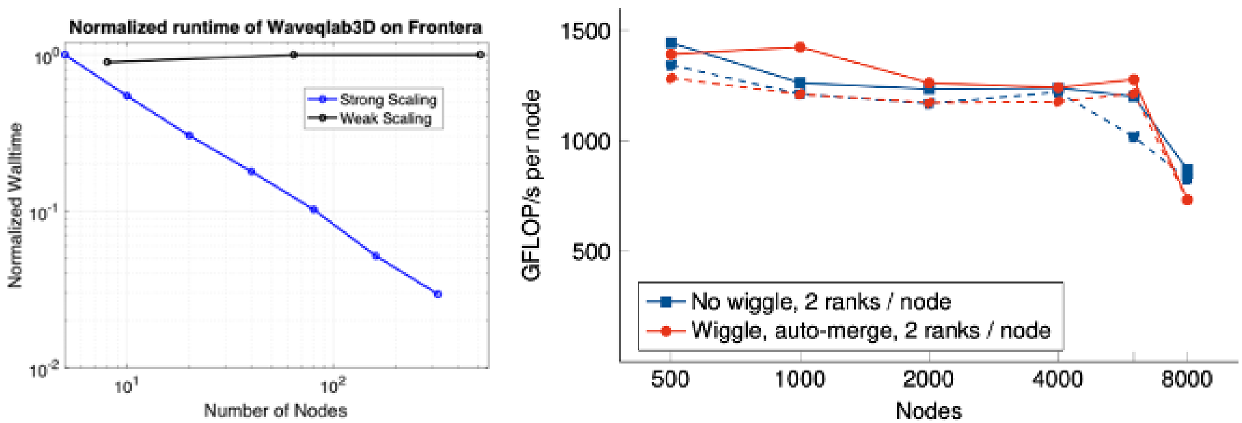

Figure 3: (left) Parallel performance of new code Waveqlab3D on Frontera. **(Right)** Recent Frontera SeisSol scaling results: Strong-scaling for a large mesh with ≈518 million elements (≈ 261 billion degrees of freedom) on Frontera. Solid lines indicate the best performance, and dashed lines the worst performance out of multiple runs.

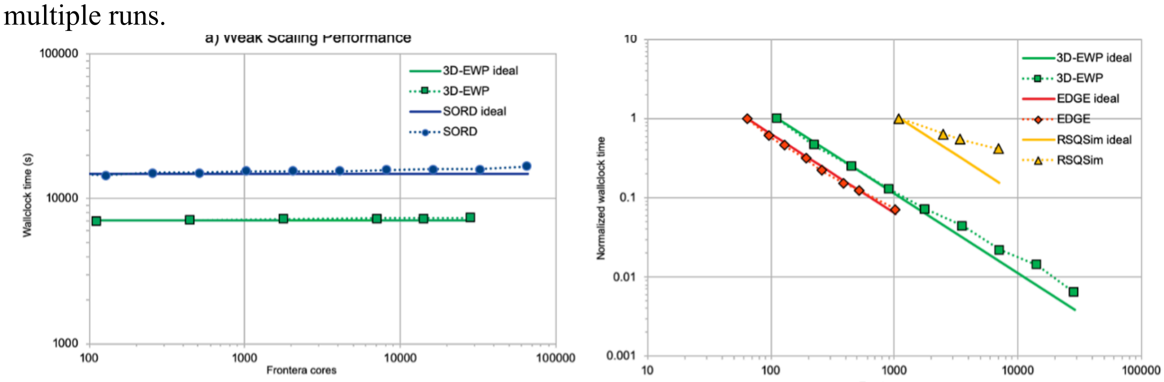

Figure 4: Code scaling performance on Frontera: problem types and sizes are different for each code. a) weak scaling for 3D-EWP and SORD with varying computational elements in each core and cores in each node. b) Strong scaling for 3D-EWP and RSQSim.

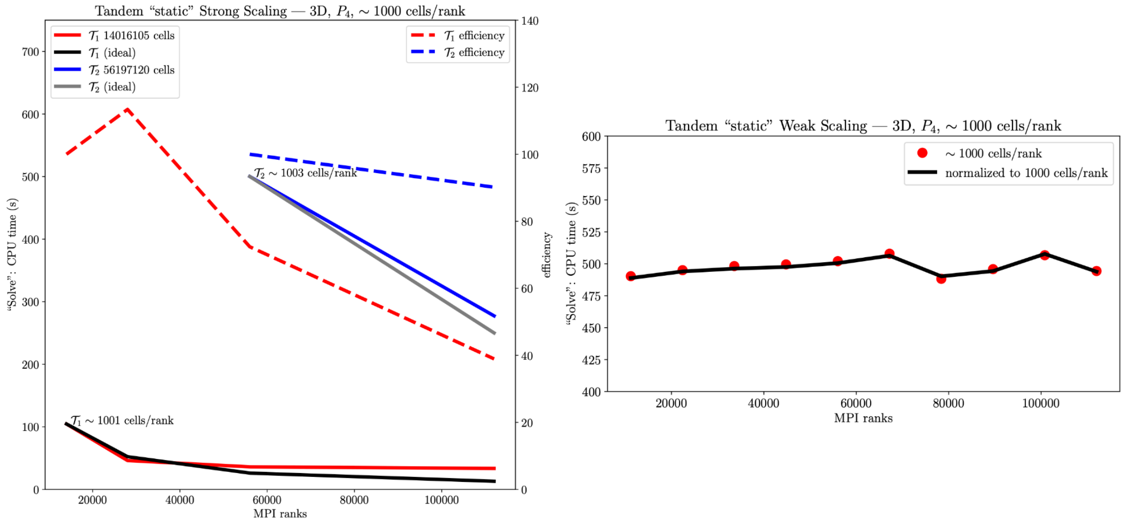

Figure 5: Tandem scaling performance on Frontera (polynomial order of 4). A 3-D elastostatic model defining a kinematic scenario of instantaneous deformation was used.with a fault network inspired by the 2019 Ridgecrest, CA, earthquake sequence. (Left) Strong scaling for Tandem with two varying computational elements. The mesh comprised 1,017,796 tetrahedral elements. (Right) Weak scaling for Tandem for about 1000 cells per rank.

6. Disclosure of Access to Other Computer Resources

Each year SCEC develops a computational research science plan and then pursues allocations for each aspect of the proposed work. We use several HPC systems to achieve our scientific objectives, and in our allocation requests, we closely match the capabilities of our codes with the capabilities of the available systems, and we avoid redundant requests. Our current additional computer resources are: **(1) USC Center for Advanced Research Computing (CARC) Discovery:** SCEC (PI: Ben-Zion) has a 250,000 SU allocation on USC's Discovery cluster. We also lease access to CARC operated servers to support our distributed Pegasus-WMS, HT-Condor-based workflow system and we have 250TB of disk storage managed by CARC. **(2) SDSC Expanse:** SCEC has a 1M SU directors discretionary (PI: Ben-Zion) allocation on Expanse that we use for research group projects, group training, and code testing. **(3) Stampede3 Director Discretionary Allocation** (20,000 SUs - PI: Maechling): SCEC is collaborating with DesignSafe-CI on ground motion simulation data management for our CyberShake project. As part of this collaboration, TACC has provided a DS-CyberShake allocation on Stampede3 to support our data migration, and data processing for our multi-terabyte CyberShake probabilistic seismic hazard models for southern and northern California. **(4) Quakeworx ACCESS Allocation** (200,000 Credits - PI: Maechling): SCEC researchers including Yehuda Ben-Zion, Alice Gabriel, Philip Maechling, Ahmed Elbanna, Philip Maechling and others are developing a geoscience-oriented Science Gateway through an NSF CSSI Award with an initial ACCESS allocation award to support gateway development and early usage. Initially, the Quakeworx gateway will dispatch jobs to SDSC Expanse. During future Quakeworx development, the project goal is to connect Quakeworx to TACC resources. **(5) DOE INCITE:** Our SCEC research group has a current 2024 INCITE award (PI: Yehuda Ben-Zion) Earthquake System Science Research on Seismic Hazard Analysis and Risk Reduction of 700,00 Node-hour on Frontier and 5000 Node-hours on Andes. We plan to submit a DOE INCITE request in June 2024 that will request approximately 550,000 SUs on OLCF Frontier for an allocation period of Jan 1, 2025 through Dec 31, 2025.

7. References (do not count towards page count)

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