Creating HPC-Based Earthquake Forecasts with SCEC UseIT Interns

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SC16

SCEC
an NSF+USGS center

USC University of Southern California

SCEC UseIT Program

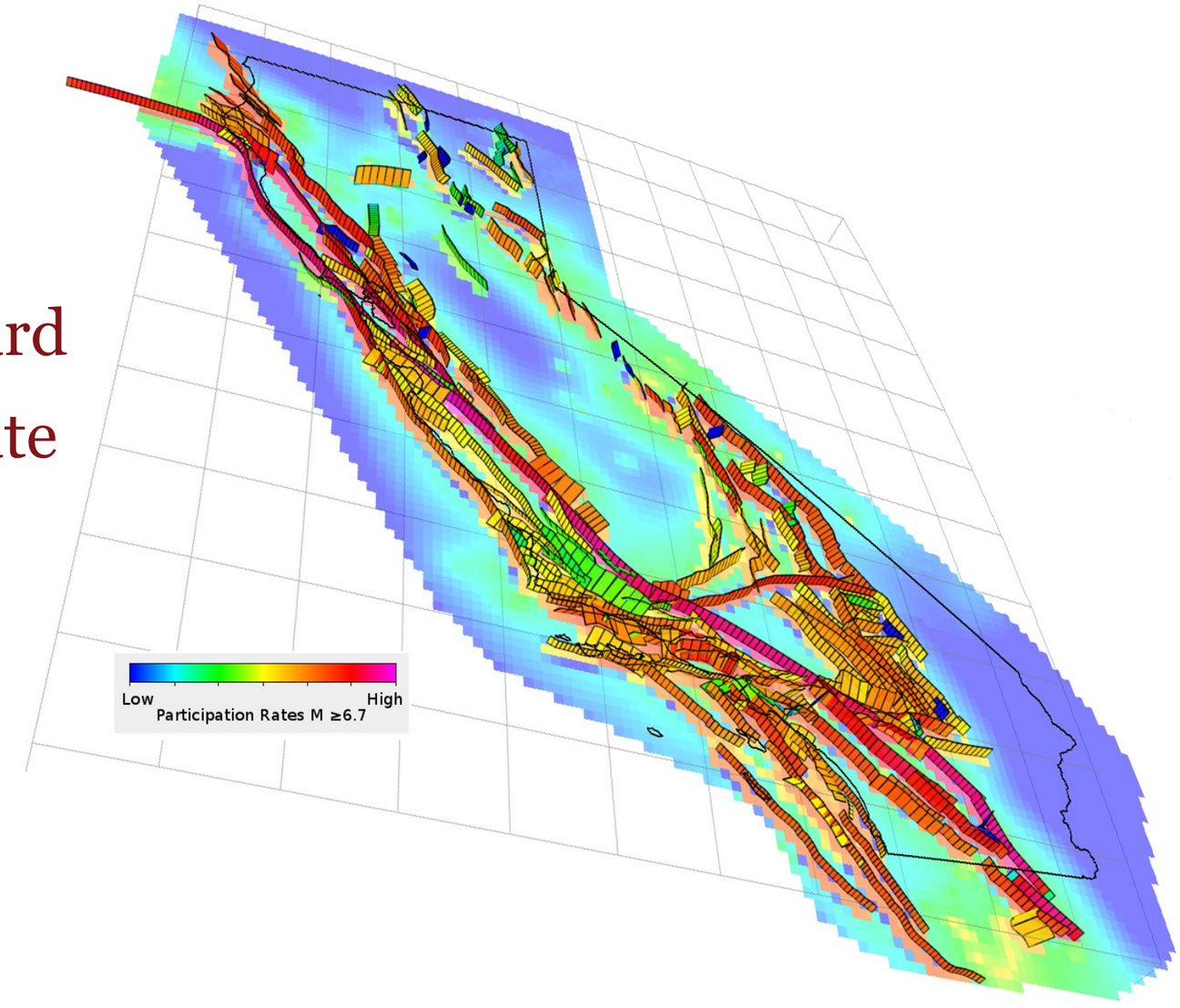
- Undergraduate Studies in Earthquake Information Technology
- Over 250 participants from 35+ institutions since 2002
- About 25 interns in STEM and media fields spend 8 weeks at USC
- Goal is to encourage careers in science and engineering
- Each year, a “Grand Challenge” is issued
- In 2016, decided to include HPC

2016 SCEC UseIT Grand Challenge

- Five main components:
  1. Use physics-based earthquake simulators on HPC resources to generate long (>100,000 years) catalogs of simulated earthquakes.
  2. From these catalogs, generate forecasts of large (M>7) earthquakes on the southern San Andreas fault.
  3. Estimate the probability of multiple large earthquakes within a short time interval (1 week, 1 month, 1 year).
  4. Compare these results to the official Uniform California Earthquake Rupture Forecast.
  5. Visualize the results.
- 58% of interns had no earth science experience
- 31% had no programming experience

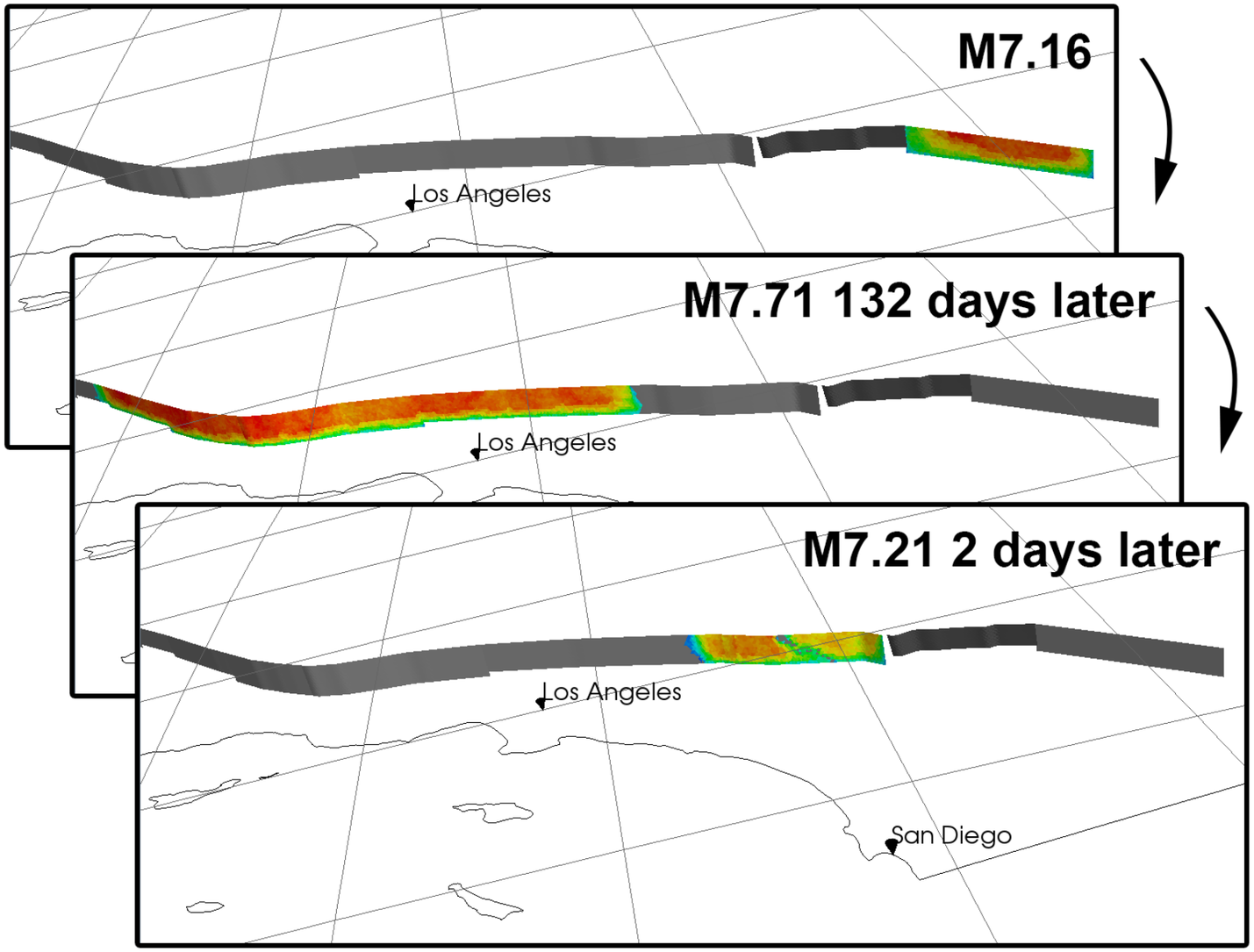
What is an earthquake forecast?

- Long-term (decades), unlike a short-term prediction
- Can identify most likely faults
- Typically, forecasts rates, not hazard
- Improvements to forecasts translate into reduced risk
- Many types of data may be used as input to forecasts
  - Historical earthquakes
  - Slip
  - Stress models



Earthquake Simulators

- Physics-based simulation of fault system
- Generate multi-thousand-year catalogs of events
- Can mine for statistics you can't get from historic catalogs
- Selected SCEC community code, RSQSim, for interns to use



UseIT Teams

- High Performance Computing team
  - Responsible for generating RSQSim catalogs
- Probabilistic Forecasting team
  - Computed statistics from catalogs to generate forecasts
- Catalog Visualization team
  - Developed in-house SCEC-VDO software to visualize catalogs and forecasts
- Hazard and Risk Visualization team
  - Computed shake maps and losses from various events
- Media team
  - Created virtual and augmented reality apps, and a documentary of the intership

HPC Team

- 5 interns with greatest interest in HPC
- Used almost 700,000 core-hrs to simulate 1M+ years of earthquakes with varying model parameters on NCSA Blue Waters
- Performed post-processing and data analysis at USC HPC
- Toured USC HPC facility
- One is at SC16 as part of the HPC for Undergraduates Program

Run Name	a Coefficient	b Coefficient	b - a	Shear Stress	Normal Stress
Base	0.01	0.015	0.005	60	100
Rate	0.008	0.015	0.007	60	100
Rate 2	0.009	0.015	0.006	60	100
State	0.01	0.013	0.003	60	100
Sigma High	0.01	0.015	0.005	120	200
Sigma Mid	0.01	0.015	0.005	90	150
Sigma Low	0.01	0.015	0.005	72	120

HPC Team: Comparisons

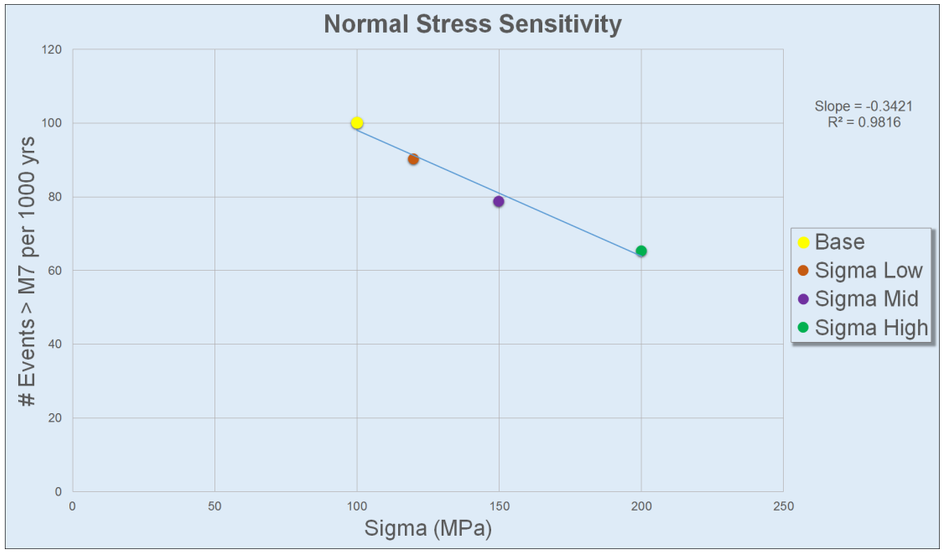
Best Fits

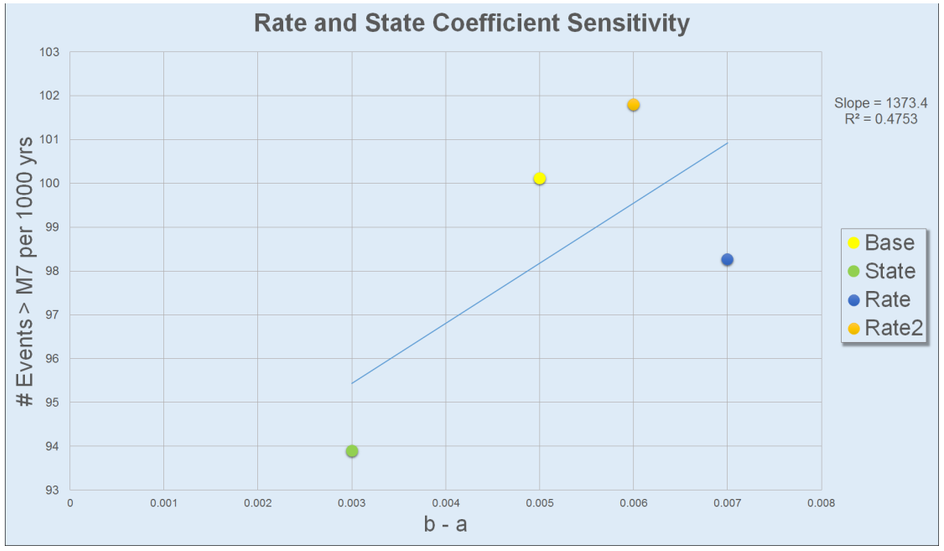
		UCERF3	Base	Rate	Rate_2	State	Sigma Low	Sigma Mid	Sigma High	Sigma High 64
# of Events ≥ M7*	CA	692.14	1076.53	1031.72	1073.01	992.90	827.01	953.28	681.70	696.50
			55.54%	49.06%	55.03%	43.45%	19.49%	37.73%	1.51%	0.63%
	SoCal	363.52	656.69	624.98	657.52	629.86	500.68	577.51	402.73	412.12
			80.65%	71.93%	80.88%	73.27%	37.73%	58.87%	10.79%	13.37%
	sSAF	107.21	192.07	199.94	205.92	209.30	140.14	168.75	107.31	108.99
			79.14%	86.48%	92.06%	95.21%	30.71%	57.40%	0.08%	1.65%
	SJF	28.06	49.33	47.62	47.21	55.23	36.84	39.60	36.01	34.85
			75.79%	69.72%	68.24%	96.82%	31.31%	41.14%	28.31%	24.18%
Recurrence Interval (yrs)	CA	14.45	9.29	9.69	9.32	10.07	12.09	10.49	14.67	14.36
			35.71%	32.91%	35.50%	30.29%	16.31%	27.39%	1.53%	0.63%
	SoCal	27.51	15.23	16.00	15.21	15.88	19.97	17.32	24.83	24.27
			44.64%	41.84%	44.71%	42.29%	27.40%	37.05%	9.74%	11.79%
	sSAF	93.27	52.07	50.02	48.56	47.78	71.36	59.26	93.19	91.75
			44.18%	46.38%	47.93%	48.77%	23.49%	36.47%	0.08%	1.63%
	SJF	356.38	202.73	209.98	211.82	181.07	271.41	252.50	277.74	286.98
			43.11%	41.08%	40.56%	49.19%	23.84%	29.15%	22.07%	19.47%

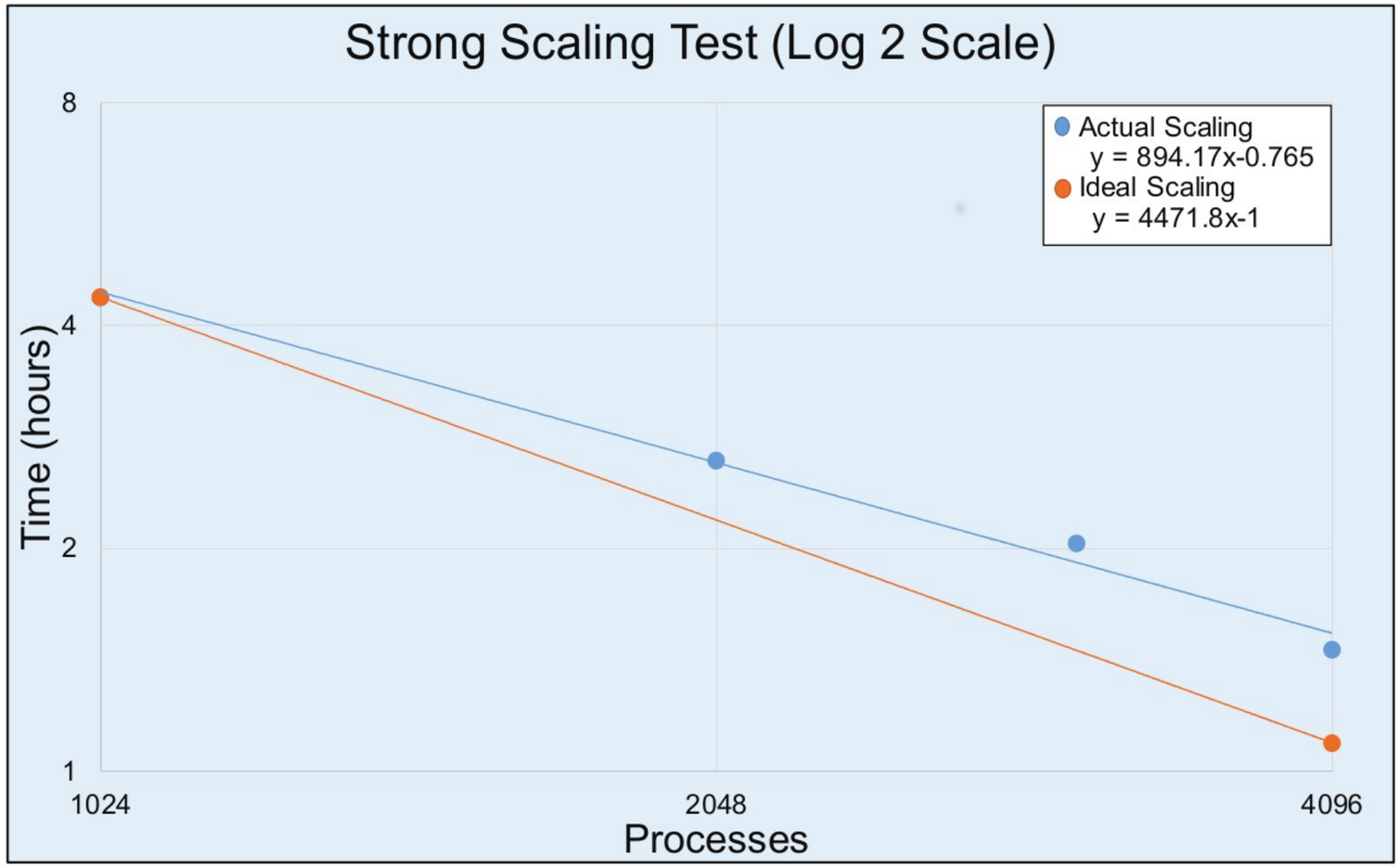
% Differences
Higher than UCERF3
Lower than UCERF3

* Average values per 10,000 years

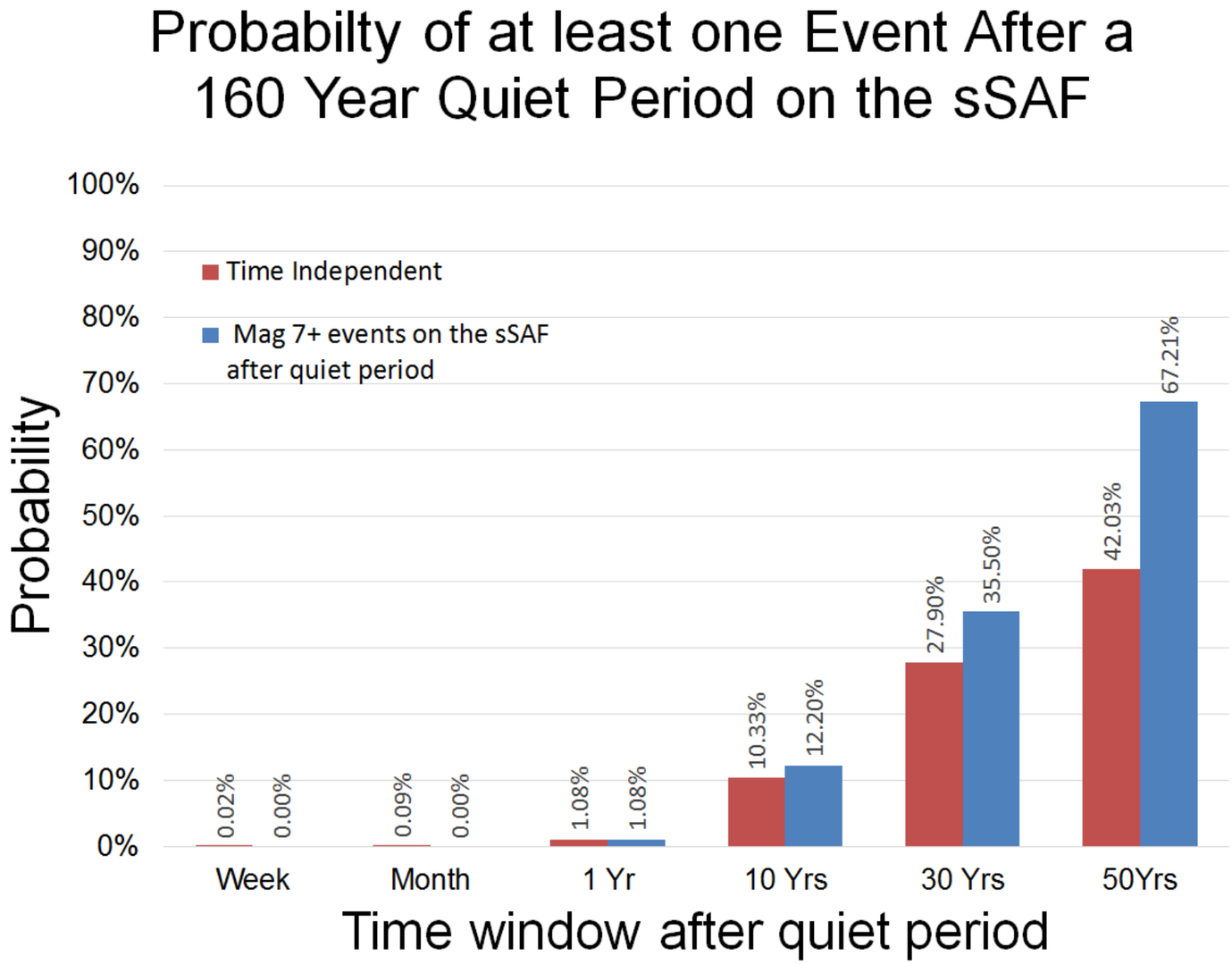
HPC Team: Results



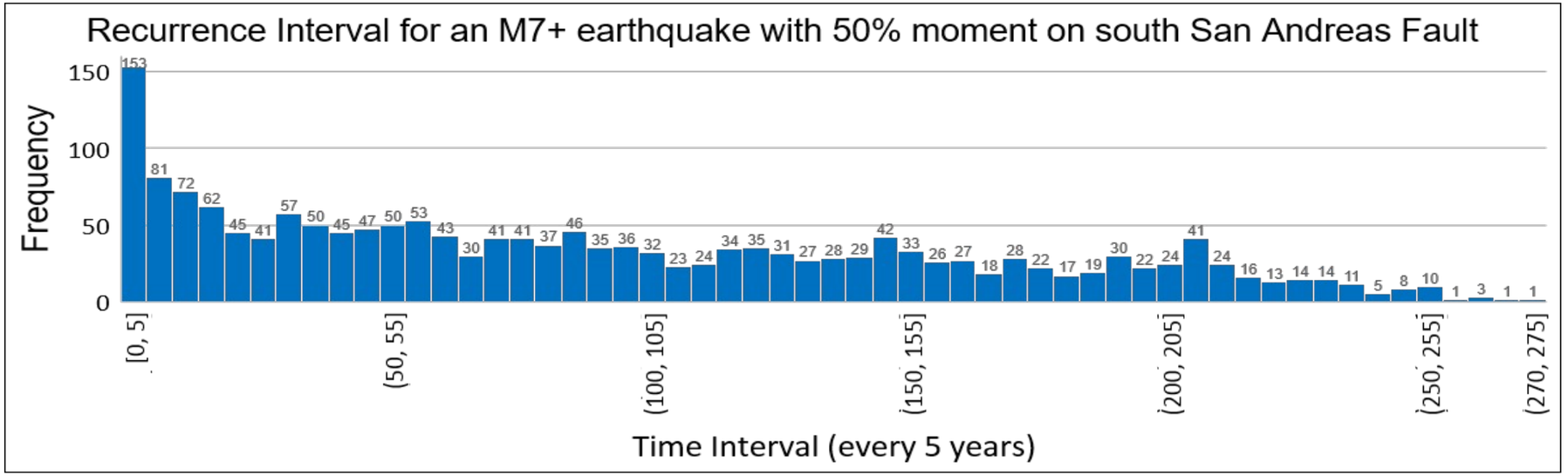




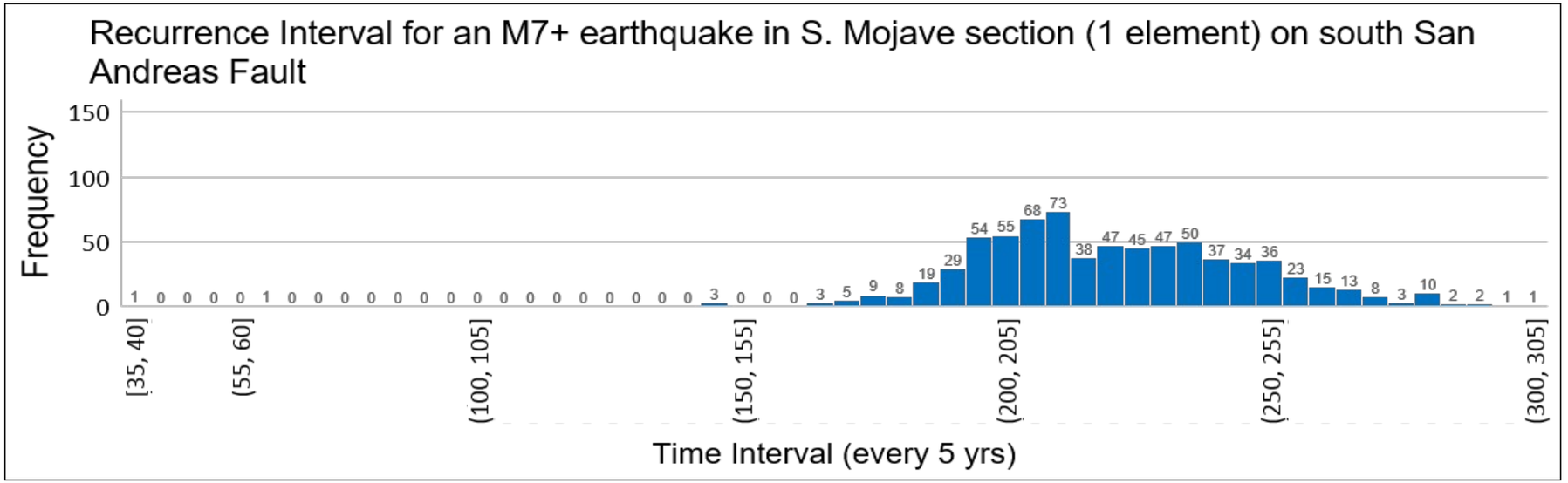
Probabilistic Forecasting Team: Results



Probabilistic Team: Recurrence Intervals

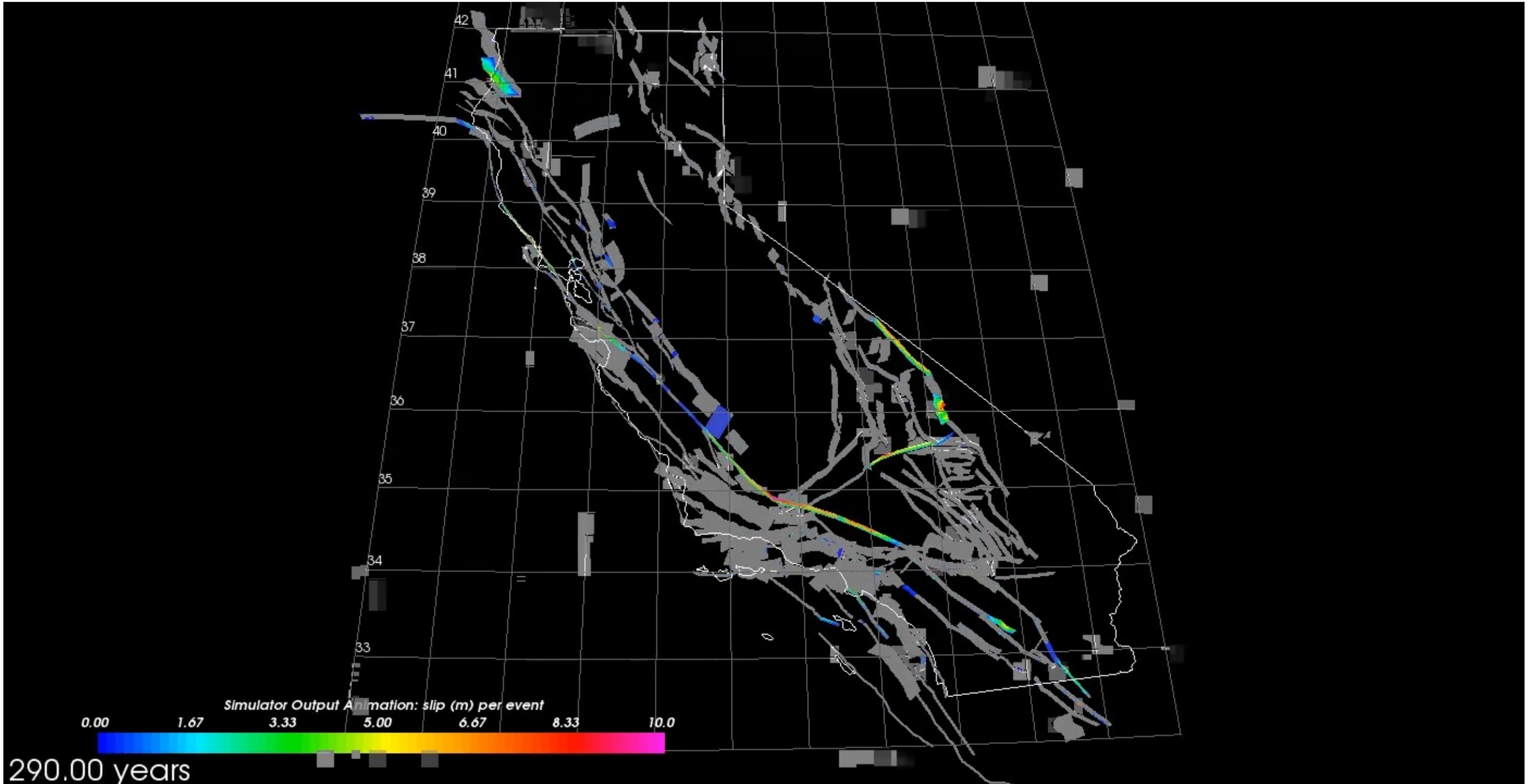


Recurrence interval:
92 yrs



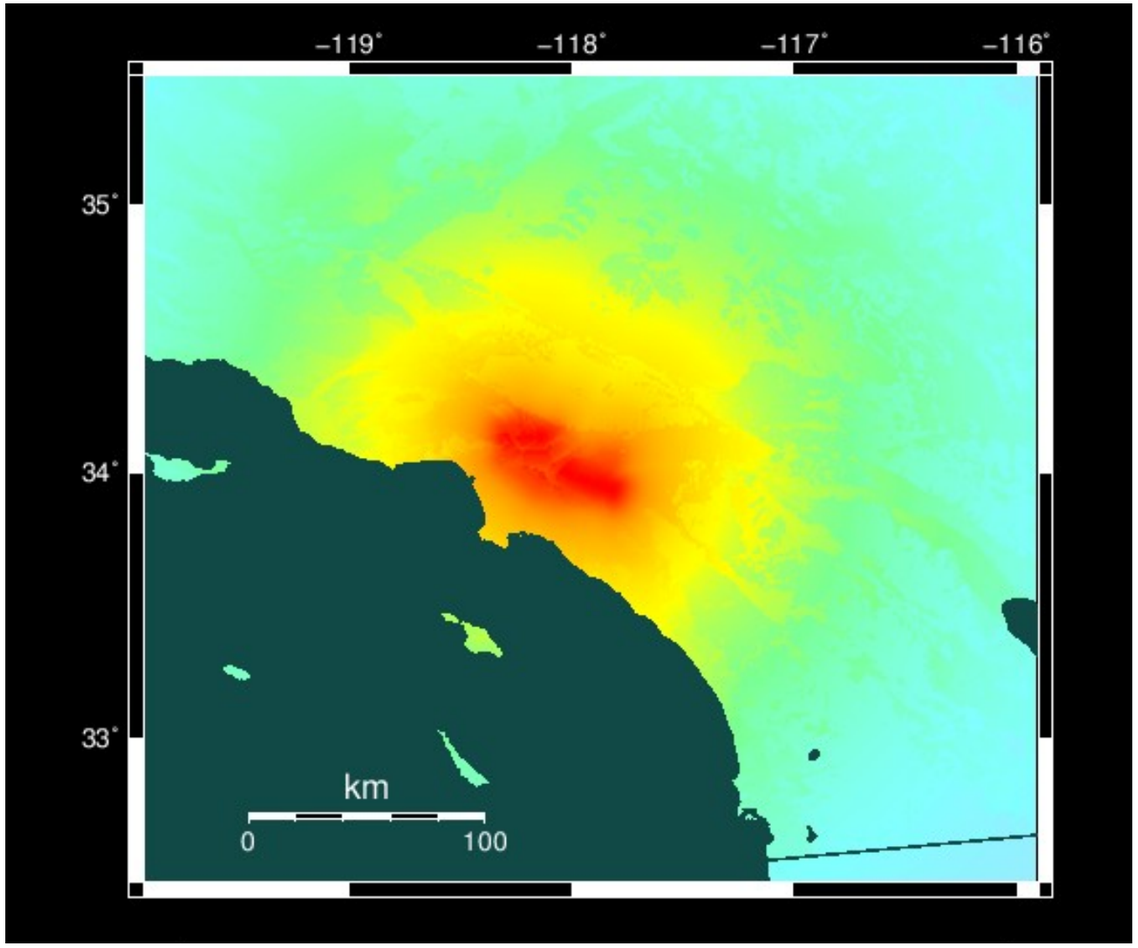
Recurrence interval:
223 yrs

Visualization Team

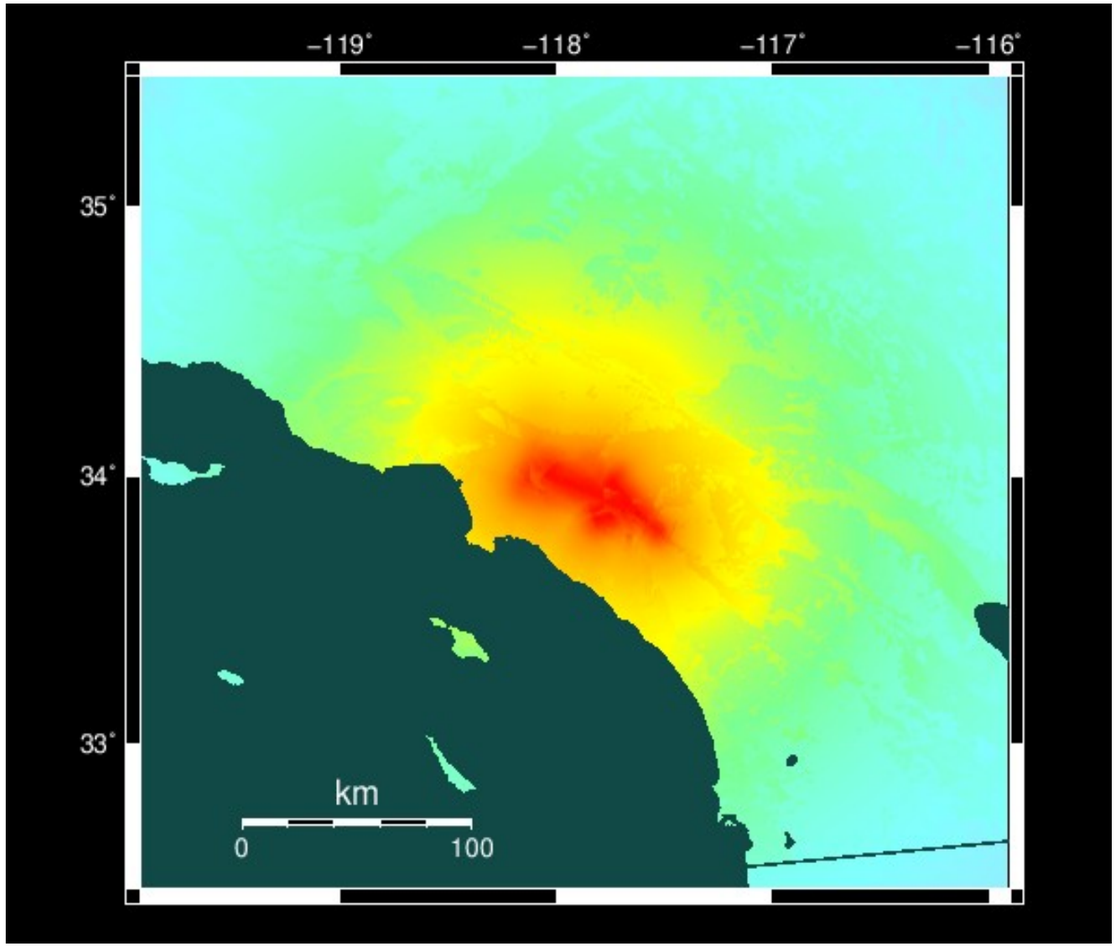


Hazard and Risk Team

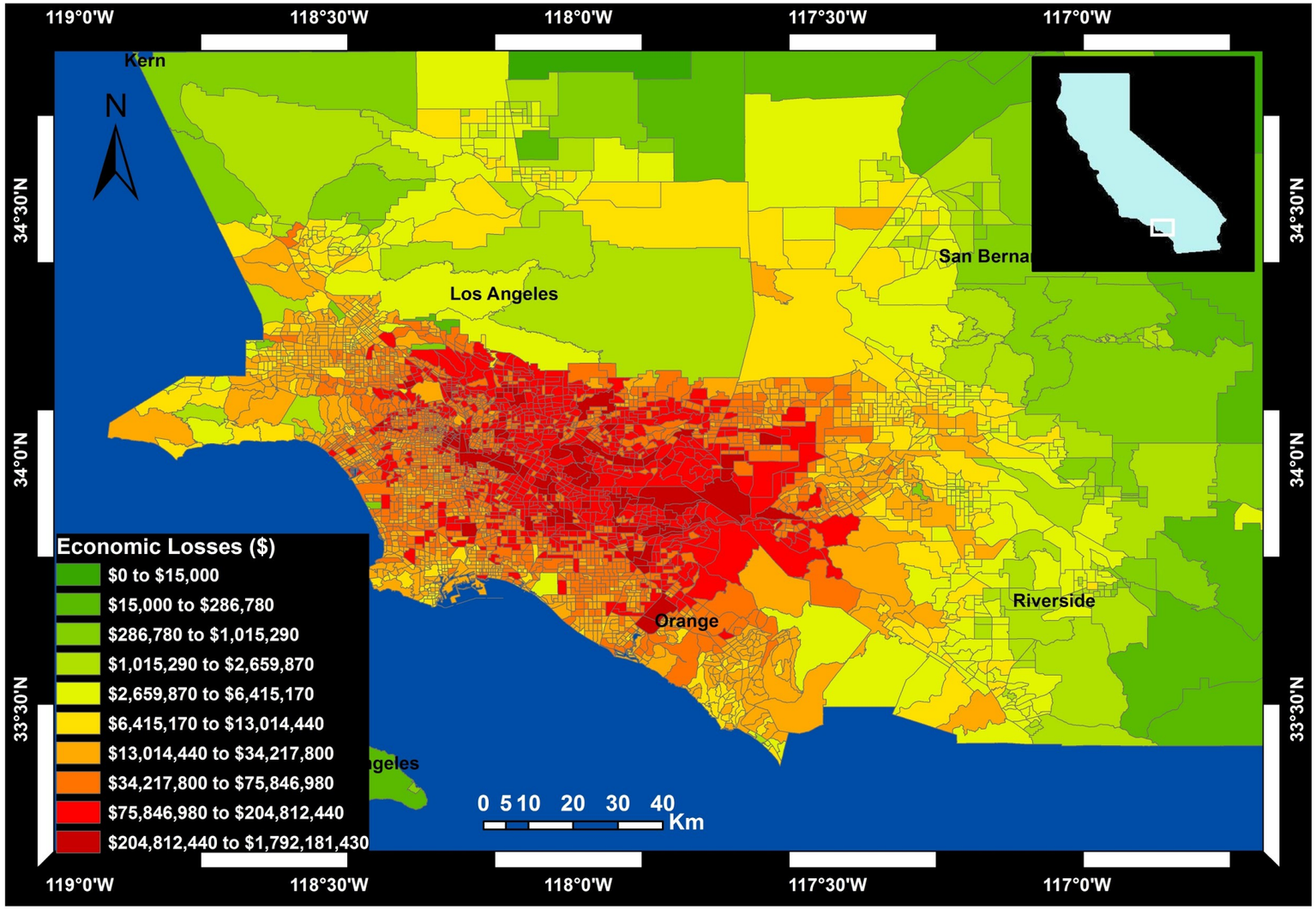
Event One: Puente Hills



Event Two: Whittier



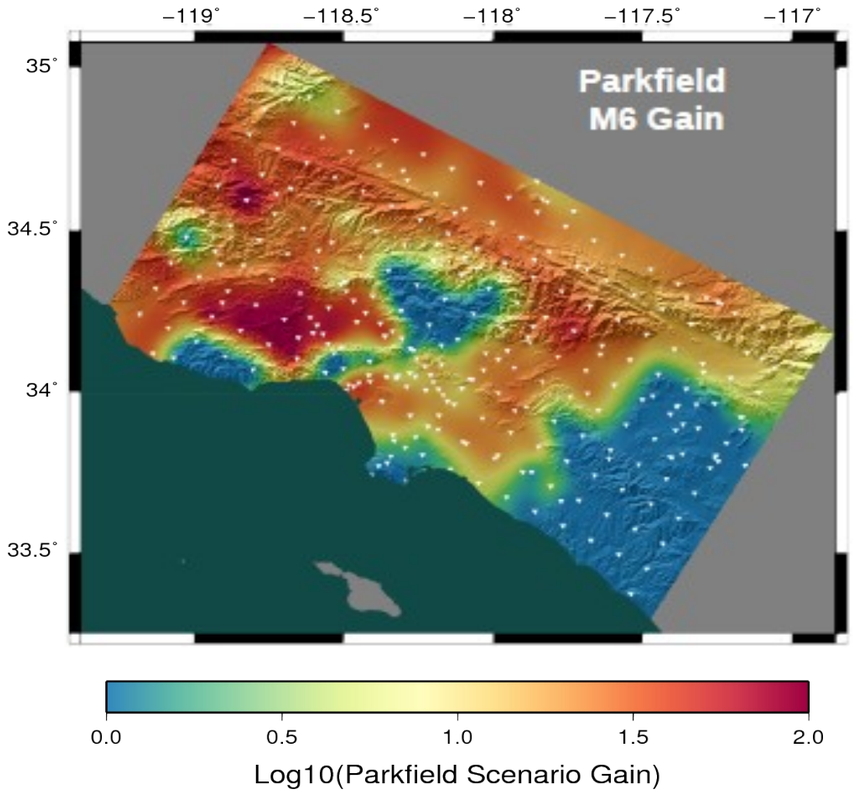
Hazard and Risk Team: Loss Estimates



Total Loss: $198,371,640,000

Future Plans

- Based on this year's success, plan to continue integrating HPC in UseIT
- RSQSim will be used for real-time operational earthquake forecasts
- Potential to integrate earthquake simulator data into next iteration of official California earthquake rupture forecast



Questions?

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ISI
Information Sciences Institute

XSEDE
Extreme Science and Engineering Discovery Environment

National Science Foundation

SDSC
SAN DIEGO SUPERCOMPUTER CENTER

TACC

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