Known Unknowns and Unknown Unknowns

Discussion of Epistemic Uncertainties and Opportunities in SCEC-5 to Tackle Them

SCEC Annual Meeting, September 8, 2014

Seismic Hazard Analysis Context

- SCEC Mission: Earthquake science for understanding hazards and reducing earthquake risk.
- Seismic hazard primary divisions:
  - Seismic source characterization: where, how often, how big
  - Ground motion characterization: what to expect in terms of ground motions at given return times.
- Ground motion estimates and risk estimates are very sensitive to uncertainties in ground motion prediction (ref. Distinguished Speaker presentation by N. Abrahamson.)

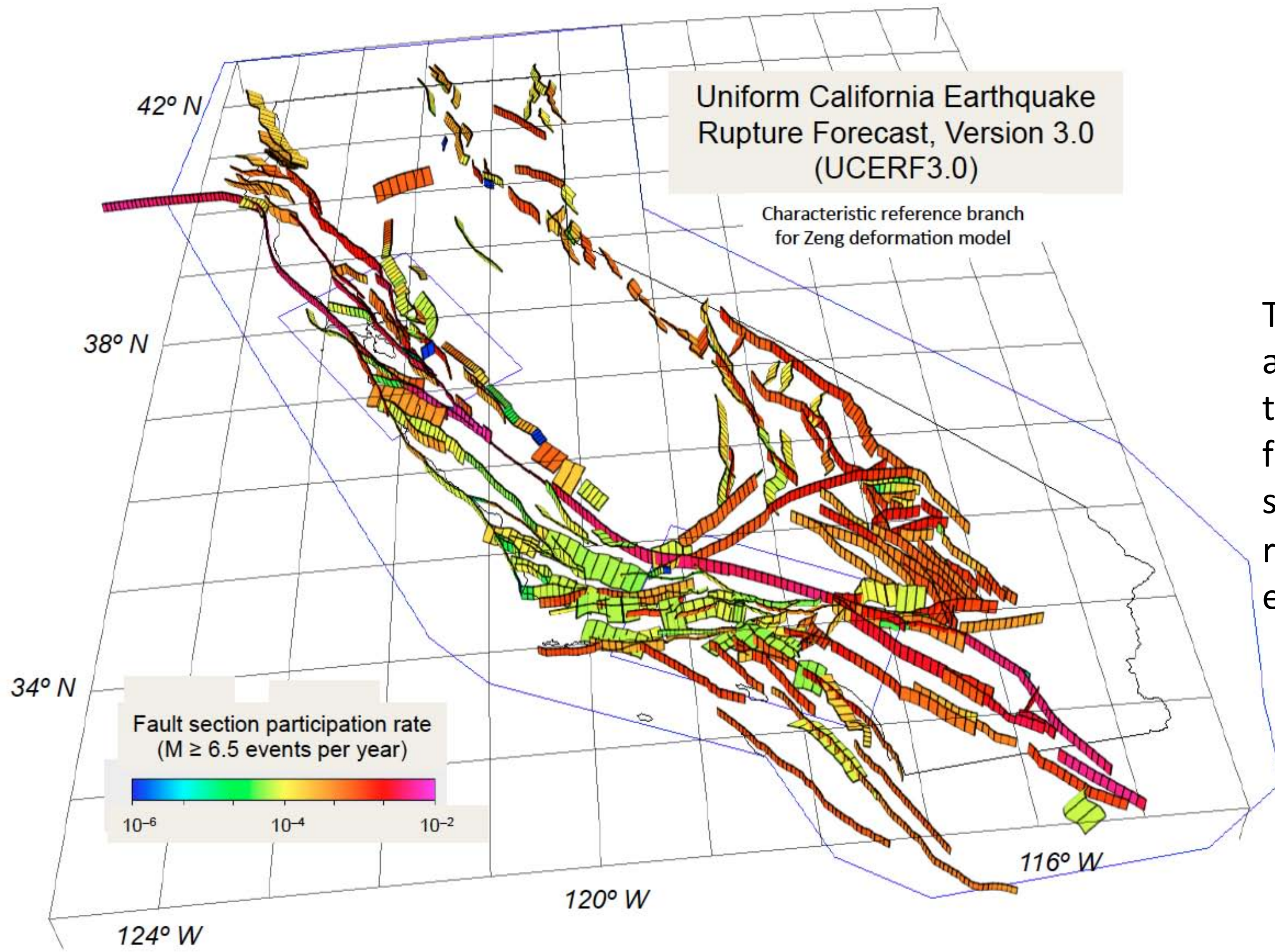
Aleatory Variability and Epistemic Uncertainty

- Epistemic uncertainty – the attribute can be known.
  - Opportunities: New data and/or methods that resolve values or reduce their uncertainties.
- Aleatory variability – random degree of system behavior; measured relative to a system model.
  - Opportunities: New physical models that make aspects knowable in advance.

Ground Motion Characterization - Uncertainties and Opportunities

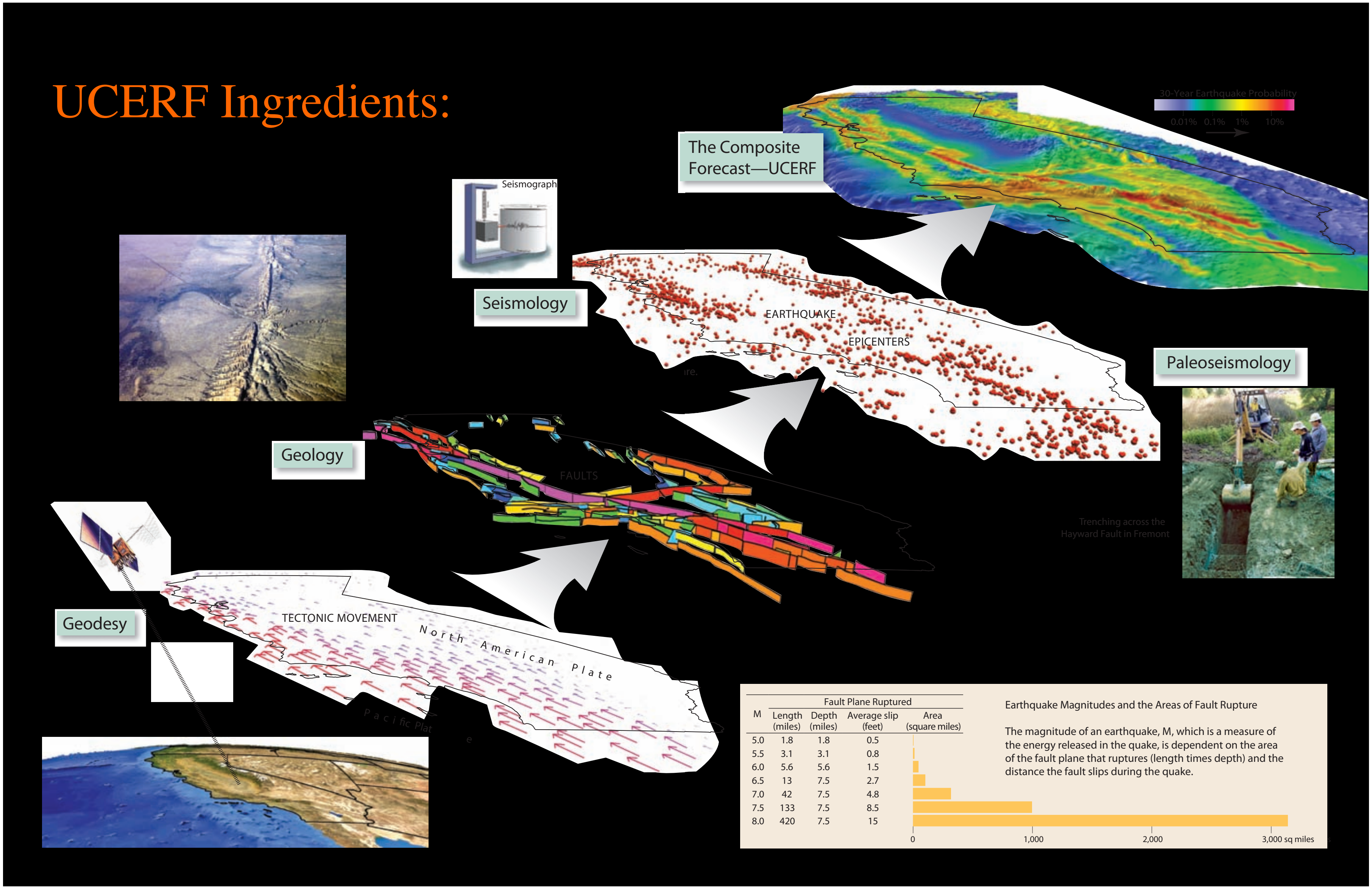
- Ground motion elements
  - Site response - amplitude, frequency, linearity
  - Path effects – Q(f,z), scattering, amplitude variations
  - Source potency/stress drop
  - Systematics of slip distribution
  - Systematics of directivity
- Syntheses and constraints on sigma
  - Averaging based factorization
  - Repeated slip at a point; repeated ground motions; unexceeded ground motions

Source Characterization: UCERF3 Example



This map: faults as discretized for the rupture forecast; Colors show annual rates of earthquakes

UCERF3: Estimates rates and magnitudes of large earthquakes



M	Fault Plane Ruptured: Length (miles)	Depth (miles)	Average slip (feet)	Area (square miles)
5.0	1.8	1.8	0.5	
5.5	3.1	3.1	0.8	
6.0	5.6	5.6	1.5	
6.5	13	7.5	2.7	
7.0	42	7.5	4.8	
7.5	133	7.5	8.5	
8.0	420	7.5	15	

Epistemic Uncertainty in Source Characterization

- Rupture definition –
  - Balance desire to include "all possible ruptures" with rupture plausibility, probability, data constraints, and inversion tractability.
  - Fault-to-fault jumps – rules, frequency, predictability
  - Slip distribution across fault-to-fault cases
  - New topologies including splays and non-simply connected ruptures.
  - Granularity of model in M <~6.7 range.
- Fault characterization:
  - location, slip rate, date of most recent activity
  - Definition of "on the fault" for separating seismicity and prospective testing.
- Seismicity –
  - Annual rate of M5 events
  - Mmax off faults
  - On-fault vs. off-fault seismicity, moment release
  - Relationship of smoothed seismicity to large ground-rupturing events
- Geodesy
  - Slip-rate constraints on faults
  - Aseismic deformation, block rotation, creep
  - Spatial smoothing kernels for seismicity
  - Origin of disagreements between geologic and geodetic rates

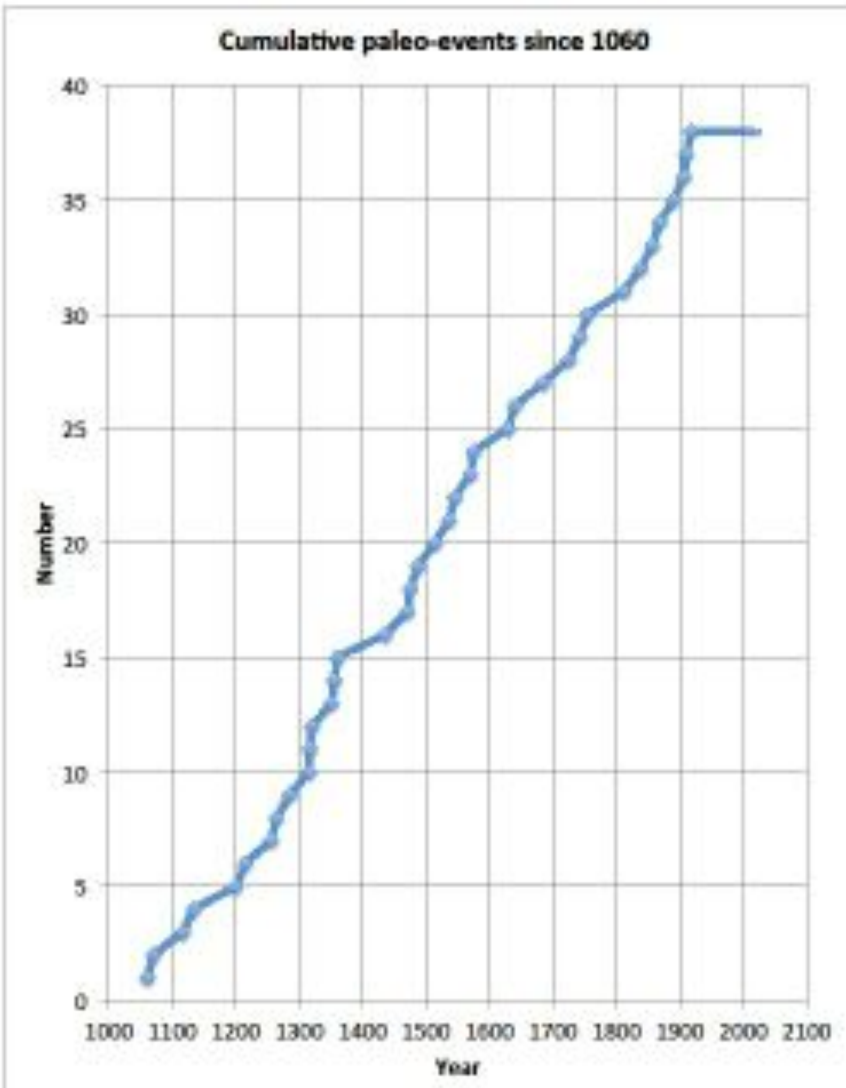
Unknown Unknowns

- Fault system complete?
- System correlations?
- Role of deep structures?
- Your idea here…

SCEC5: Taming Epistemic Uncertainties

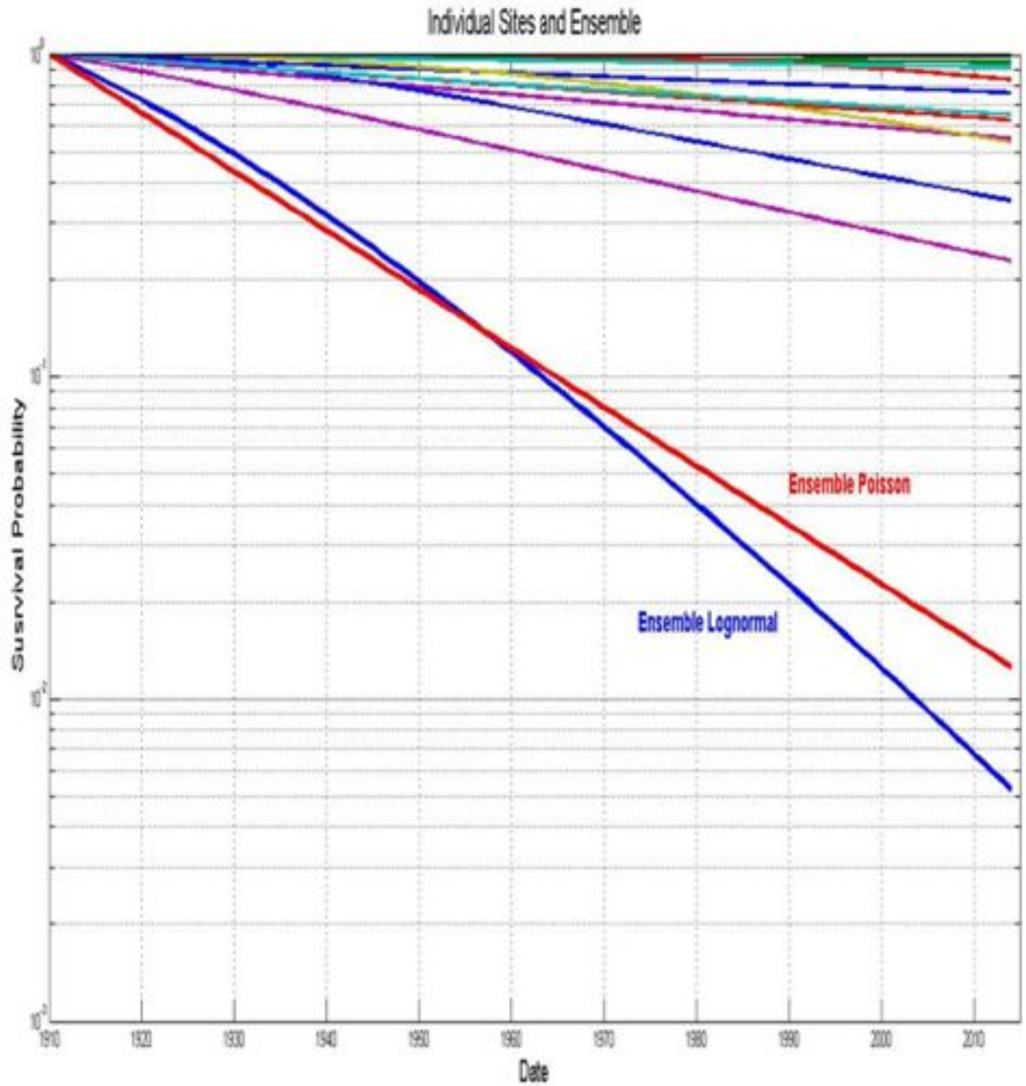
- Ground motion characterization –
  – site, path, velocity structure, predictable parts of source variability, potency, directivity…
- Seismic source characterization
  – Rupture definition, fault characterization, seismicity, geodetic constraint, off-fault and background behavior, geologic/geodetic/dynamic modeling reconcilliation
- Unknown unknowns

Cumulative paleo events since 1060



- UCERF3 employed paleo-seismic data to infer rates at 32 sites. The latest event at any of those sites was in 1910.
- Some quakes reach more than one site, so to identify double counting I estimated lower limit rate using 12 sites on separate faults
- Rate estimate was 0.04 events per year. Poisson prob of no events in 100 years is about 1% (upper limit)

Survivor function for 12 active paleoseis sites in California



Implications

- If hiatus is just **rare luck**, all is fine. Rate of future fault-rupturing rates should be as estimated from past data, e.g. 0.04 paleo-events per year if Poissonian. For lognormal model, long term average rate would be similar, but current rate would be higher because more faults are overdue. But, you would have to accept 1% probability of rejection. If so, shouldn't 1% be the standard of rejection for all data? Then uncertainties would be huge.

- If **unmodeled clustering** caused the hiatus, then future earthquake probabilities would be subject to the same effects. Would the hiatus be over soon, or continue for another century or more? Most (all?) our modelling of recurrence would go out the window.

- **Data errors**, and in particular mistaken identity of non-seismic effects as earthquakes, may have caused over-estimation of past rates before the age of instrumental seismology. If so, then both the event rates and the inferred recurrence properties, including quasi-periodic recurrence, would be out the window.
- **Got a better idea? Email me, and please explain the numbers!** **david.d.jackson@ucla.edu**

More!

- Poster: Lucky # 13
- Discussion: 5:30 – 7:00 Tomorrow (Tuesday) at Oasis II, 2nd floor, N end of building.