Performance-Based PFDHA Using the Third Uniform California Earthquake Rupture Forecast

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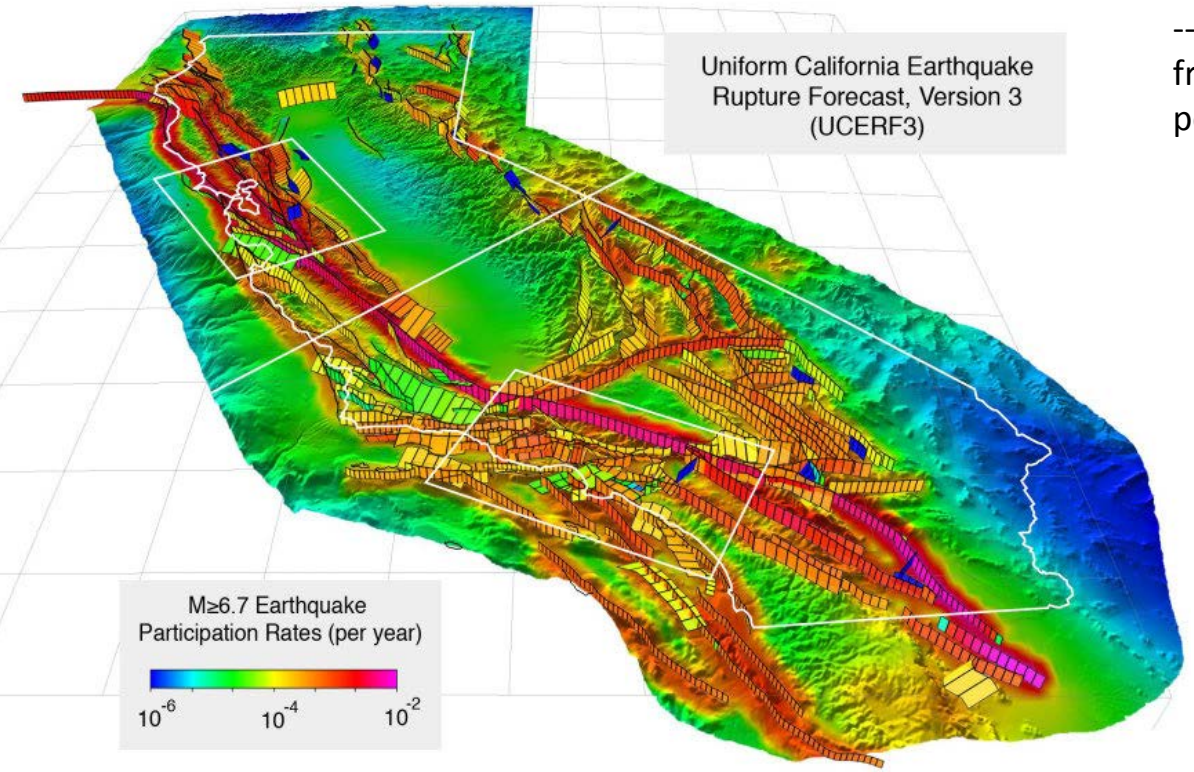
UCERF3 Model

- UCERF3: State of practice earthquake forecast for California (Field et al., 2014, 2015)
  - Covers *known active faults* with *slip rates*
  - New: fault-to-fault connectivity; unsegmented
  - Basis for USGS fault slip hazard in California



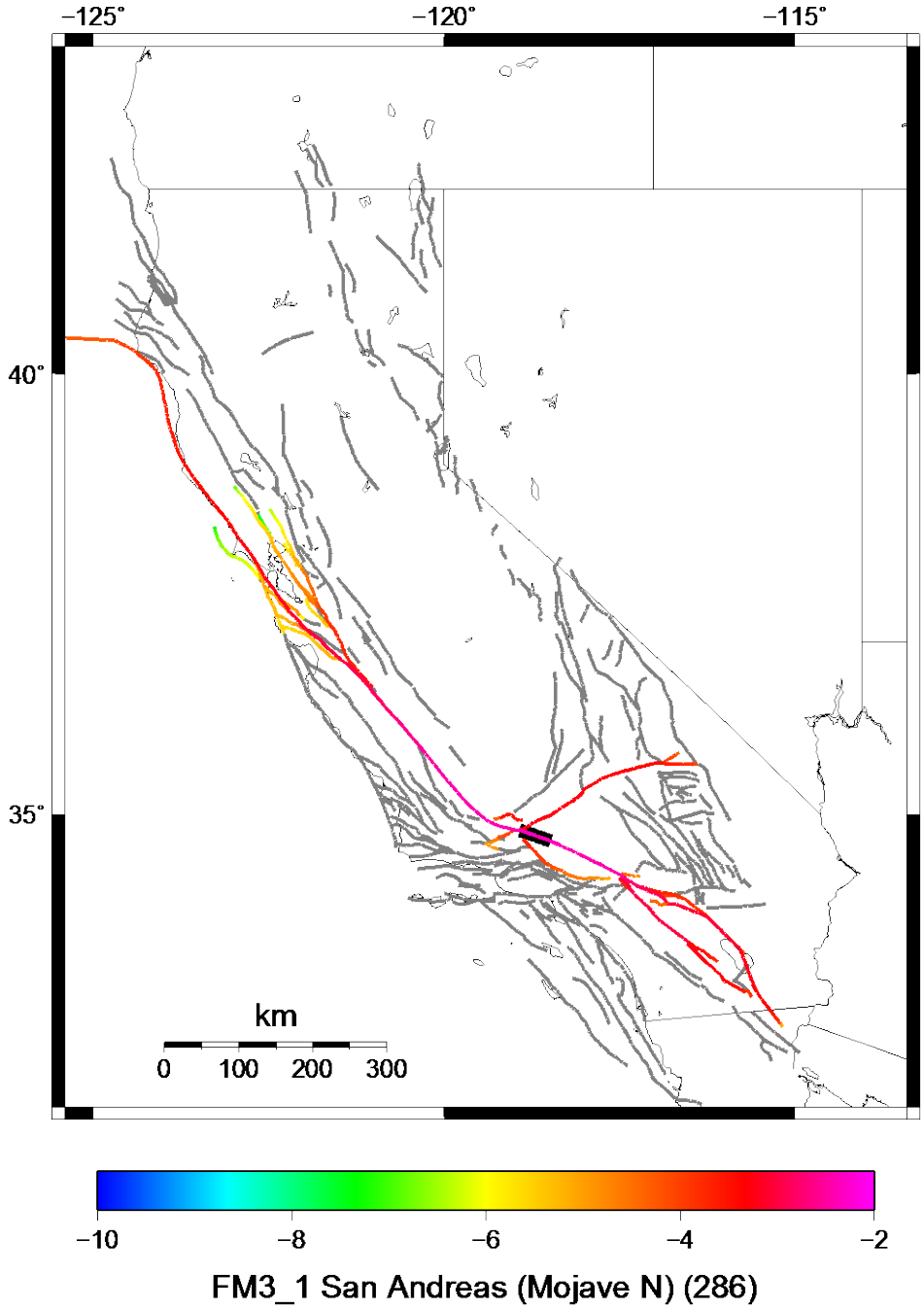
-- Faults comprised of ~7x14 km "subsections".
-- Unique combinations make >253,000 ruptures in FM3.1, >306,000 in FM3.2.
-- Each rupture gets an annual rate ("Grand Inversion").
-- Displacement hazard at a point comes from the subset of ruptures passing the point.

Non-UCERF3 faults still require traditional FDHA methods.

What Is Included With UCERF3

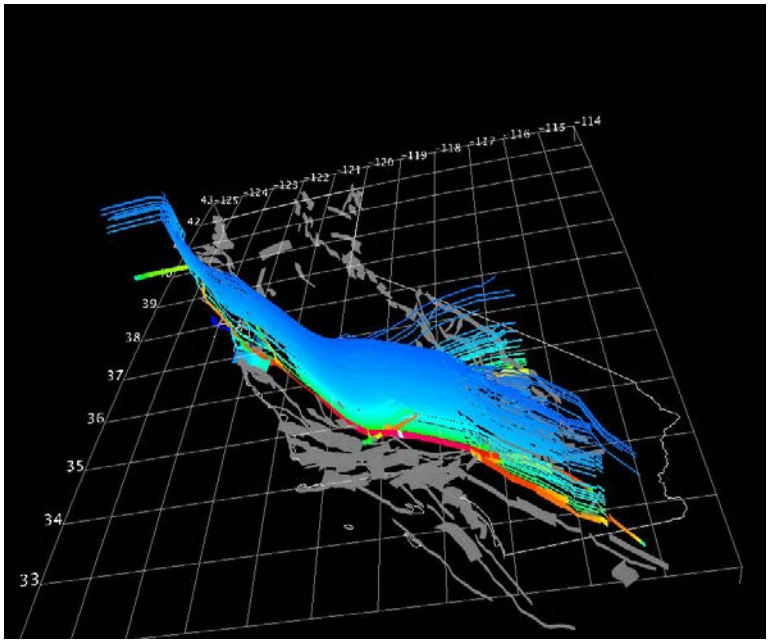
The earthquake rupture forecast provides many PFDHA parameters

Factor	From UCERF3
Earthquake magnitudes and rupture lengths	Yes
Site location in ruptures	Yes (user computes x/L)
Probability of surface rupture	Yes
Rupture rates	Yes
Displacement per rupture	Yes
Fault location uncertainty	No, only a nominal location
Width of fault zone	No, not considered
Co-seismic/post-seismic ratio	No, not included
Epistemic uncertainties – slip rate, fault geometry	No, one nominal geometry. Deaggregate first to adjust slip rate
Faults not in UCERF3 model	No, full PFDHA required



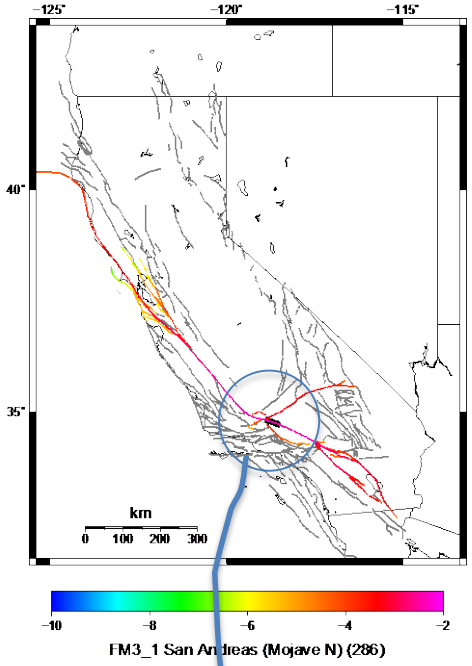
Challenge of UCERF3 Ruptures

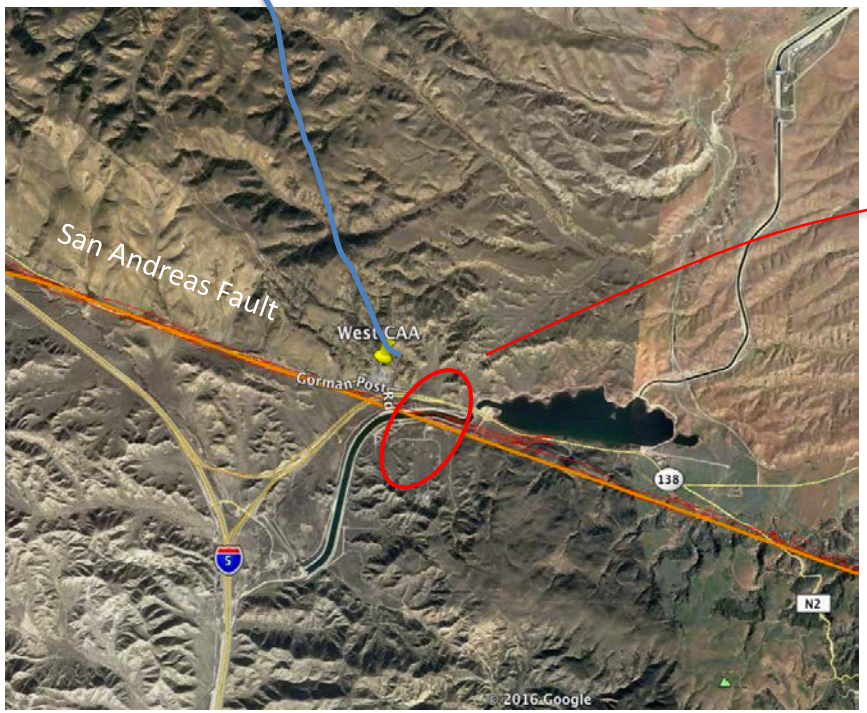
- Long, complex ruptures.
- Choices including maximum considered event not straight-forward.

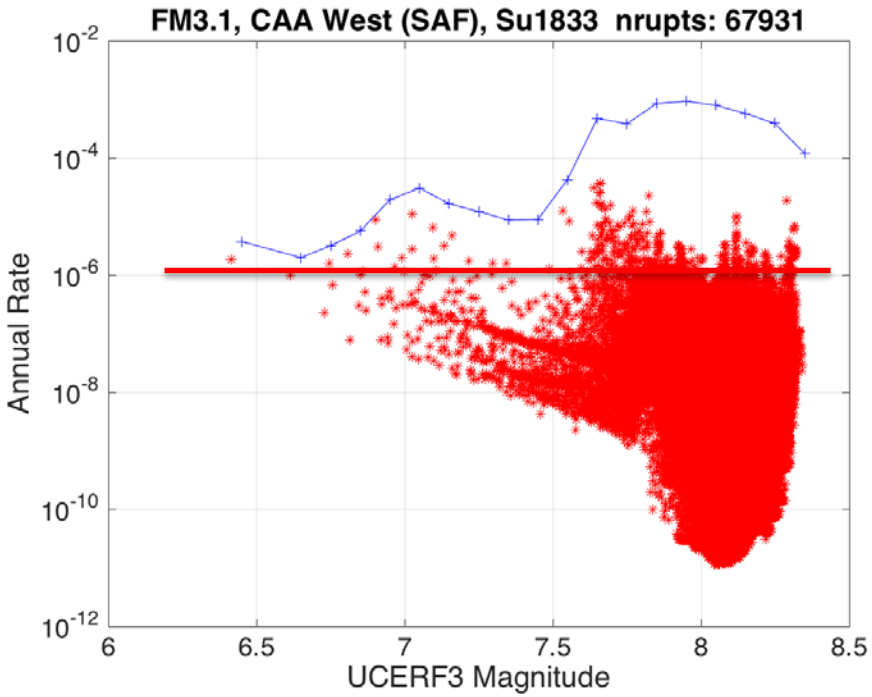


Left: Ruptures using the Mojave North section of the San Andreas fault.
Above: 200 of ~70,000 ruptures passing Mojave N.

Subset ruptures affecting the fault crossing





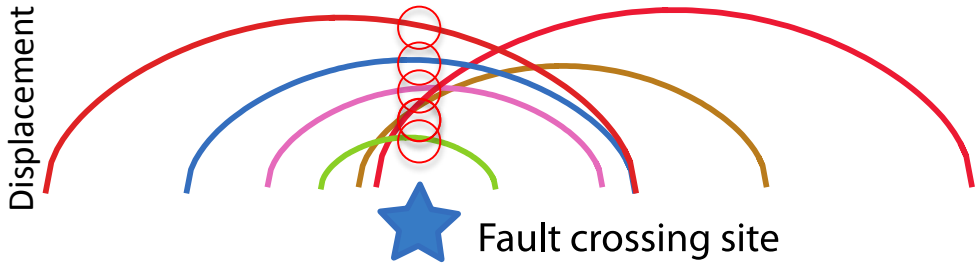


Left: Example SAF crossing by the California Aqueduct.

Above: 67,931 ruptures pass this California Aqueduct crossing of the San Andreas Fault. Red dots: individual rupture magnitudes and annual rates; Blue line: summary on 0.1 M units

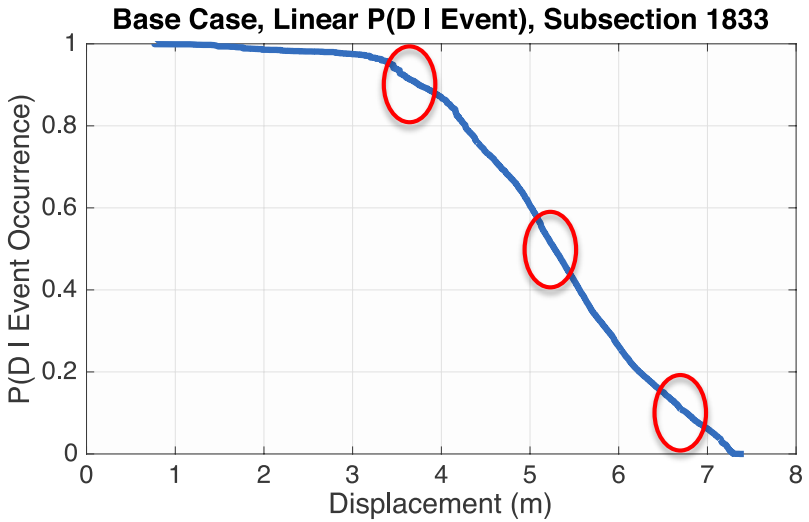
California Aqueduct “CAA West”, Ridge Route area, east of I-5.

From per-rupture displacements to fault displacement PDF



Model displacement profiles

- Gather rupture profiles from crustal earthquakes
- Average displacement shape after normalizing by AD and L is a “rainbow”
  - Below average displacements near rupture ends, above average in the middle.



Probability that D will be greater than the horizontal axis value

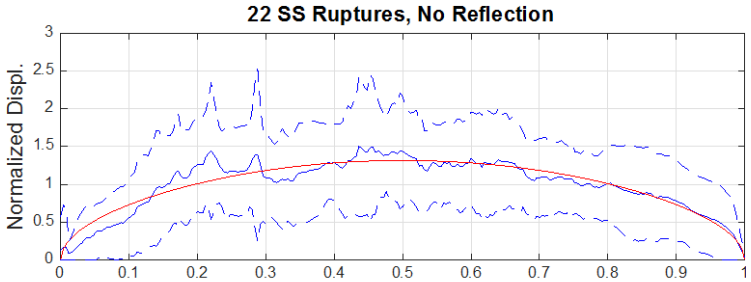
- UCERF3 provides P(R), L, AD; add location of site in rainbow to get nominal rupture displacement.
- Sort by displacement, accumulate probability to get P(D|Event) at this fault crossing.

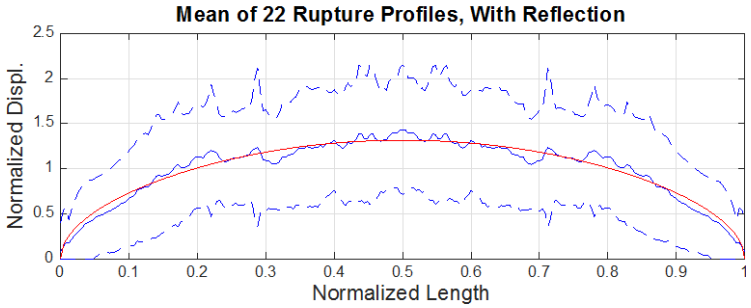
- Example: West CAA crossing. D_{50}: 5.2 m; D_{10}: ≤3.6 m; D_{90} ≤6.6 m

Adding Displacement Variability in Ruptures

- Summarize rupture variability from mapped ruptures
  - Normalize as D_{obs}/AD
  - Normalize to unit length
- SS ruptures:
  - same average shape across subsets
  - variability depends on subset of lengths
  - longer ruptures are somewhat less variable

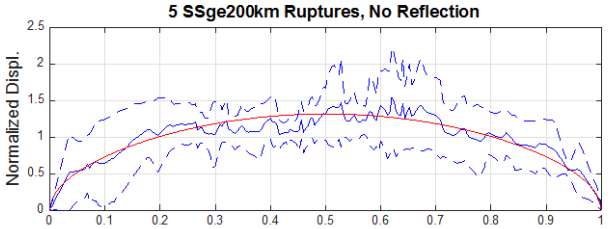
All SS ruptures

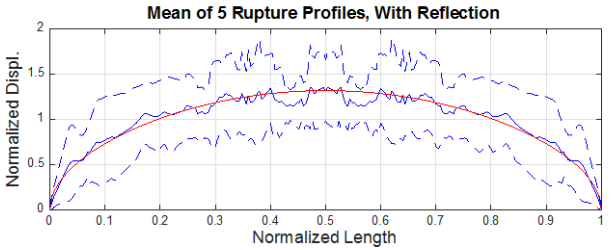


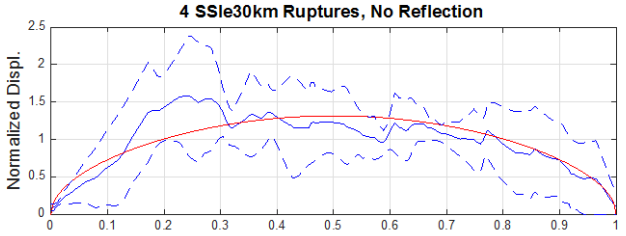


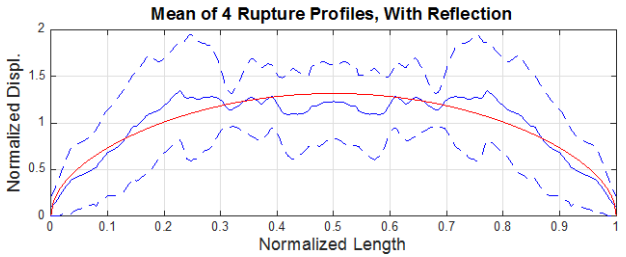
Red analytic curves are not fit to the data, just drawn over it

SS ruptures >200 km





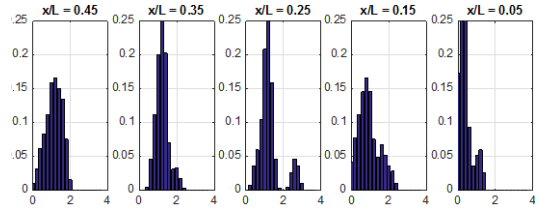




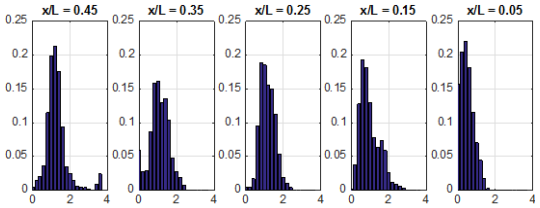
SS ruptures <30 km

Displacement PDF depends on variability model

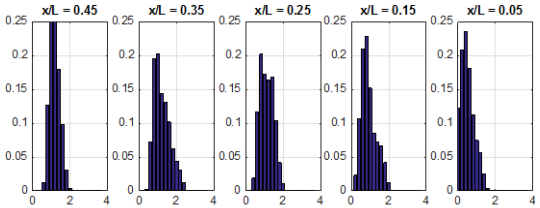
- Displacement variability depends on distance from rupture end
- Parameterize by x/L, x=distance from end, L=rupture length.
- Draw variability from histograms of empirical observations.



SS <= 30 km



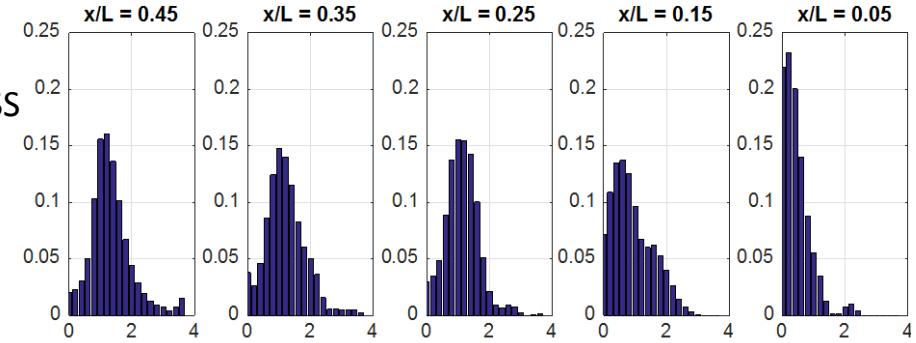
SS >100 km



SS >200 km

Fractional variability depends rupture length
=>Apply rupture-length-specific fuzz

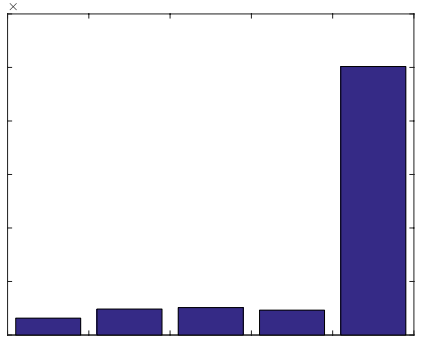
All SS



0.5>=x/L>0.4

0.1>=x/L>0

x in L distribution
(CCAW site is mostly middle of long ruptures)



0.1>=x/L>0

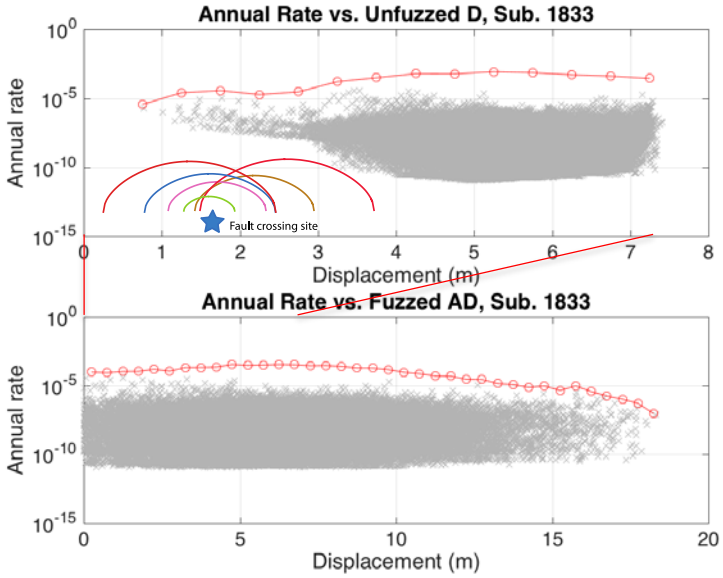
0.5>=x/L>0.4

West California Aqueduct SAF Crossing

Best estimate: “fuzz” UCERF3 ruptures using length matched empirical variability (so fuzz long ruptures with variability from >200 km SS ruptures).

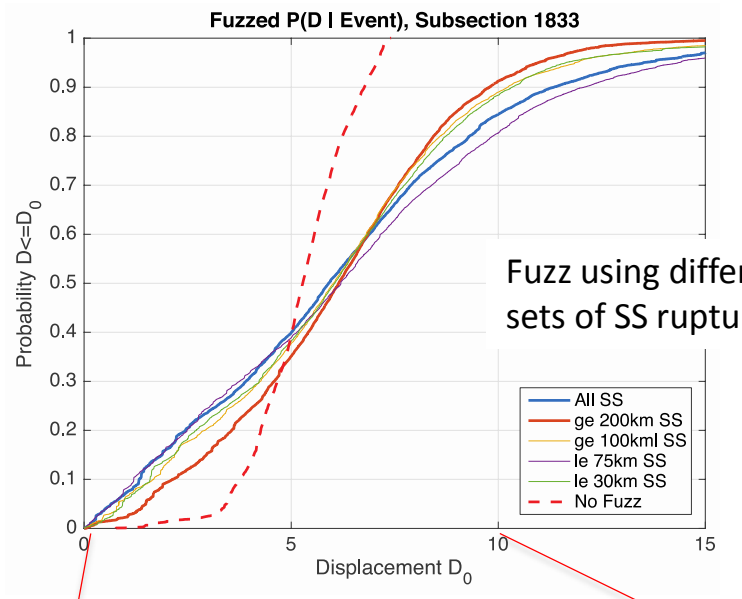
Result: Displacement-probability pairs for performance-based engineering input:

D_{50}: 6.2 m
D_{10}: 2.2 m
D_{90}: 9.7 m

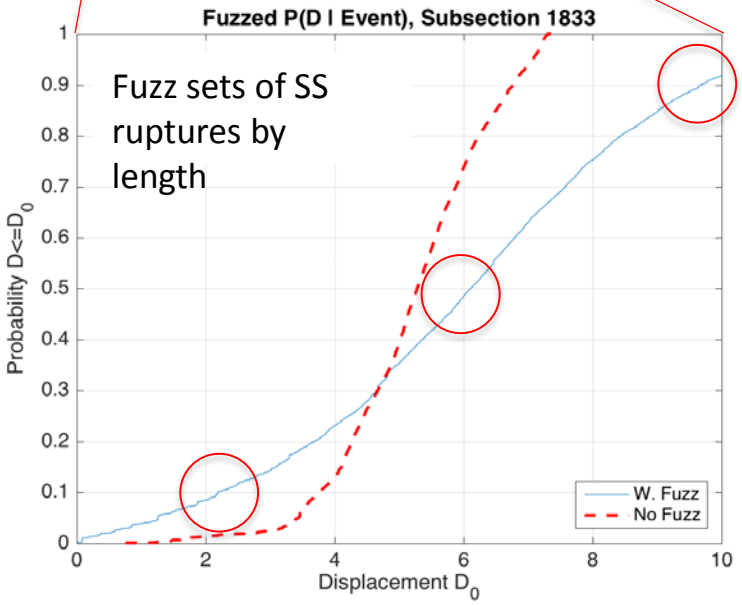


Variability fills in small and large displacement fractions

Probability given an earthquake ruptures at CAAW site

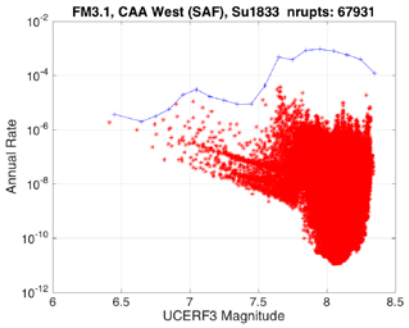


Fuzz using different sets of SS ruptures

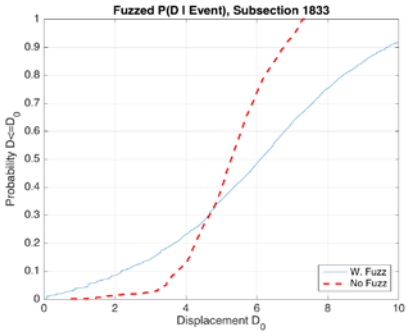


Displacement vs. Return Time

West California Aqueduct SAF Crossing



UCERF3 magnitude, annual rate of ground rupture



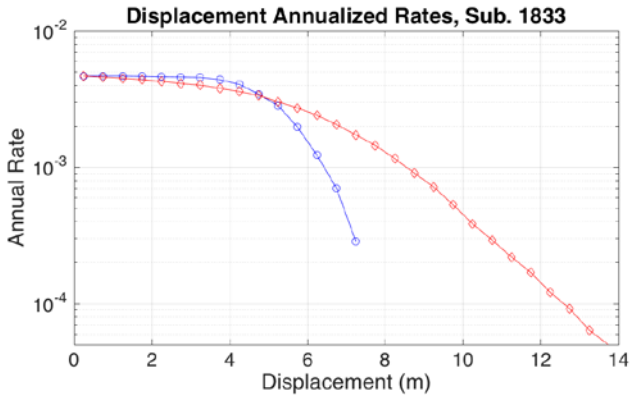
CDF of displacement given ground rupture

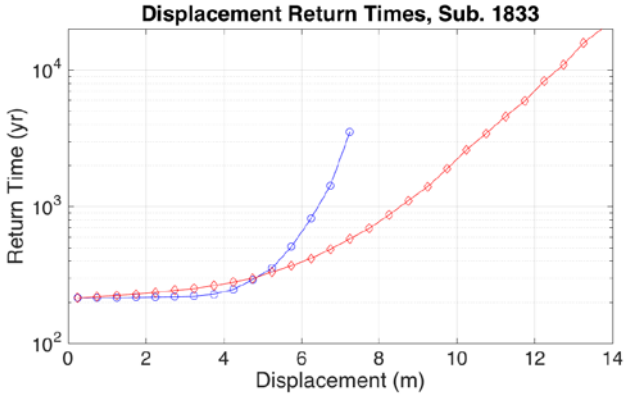
Combine displacements with UCERF3 rupture annual rates =>

- Displacement vs. Annual Rate
- Displacement vs. Return Time

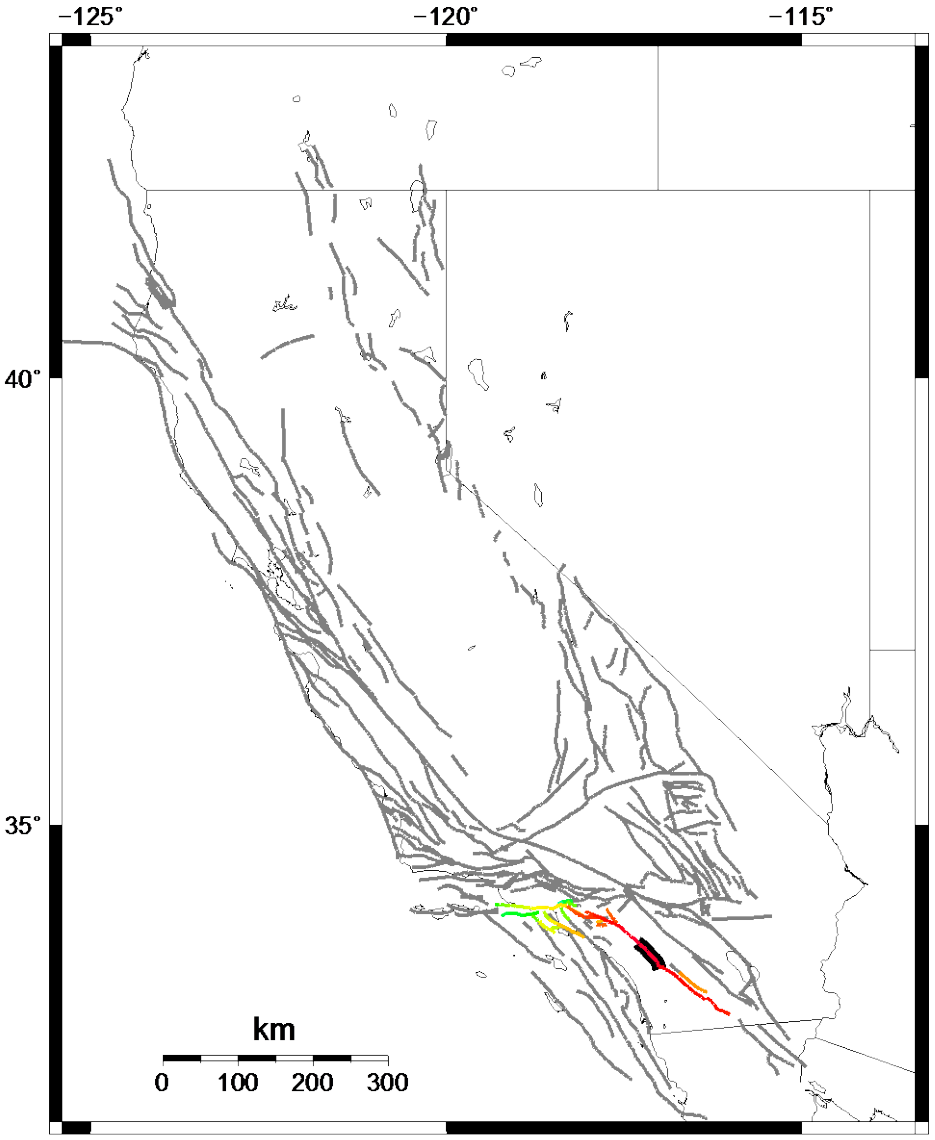
Red: length-matched variability

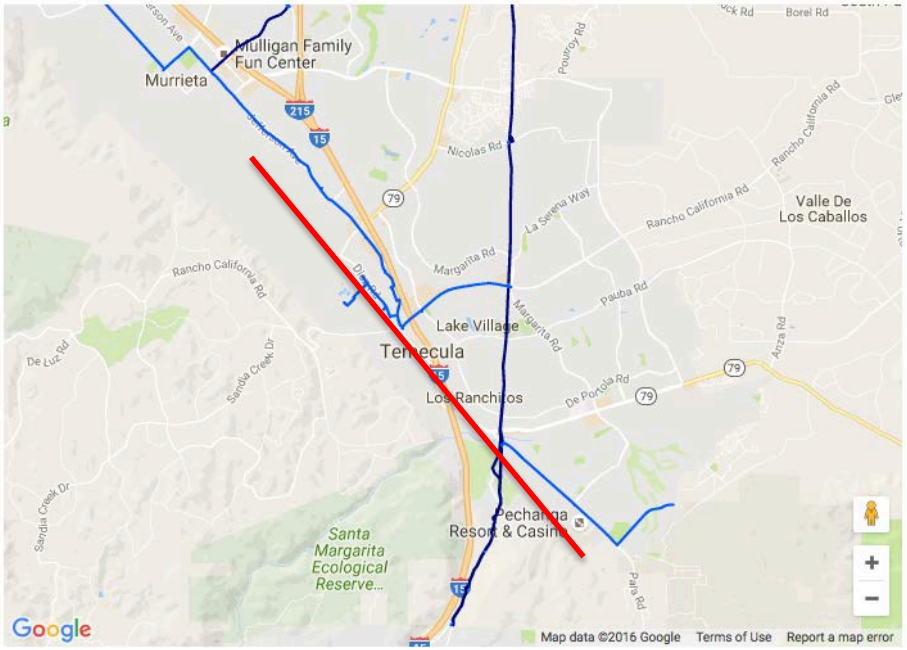
Blue: rainbow model only; no fuzz



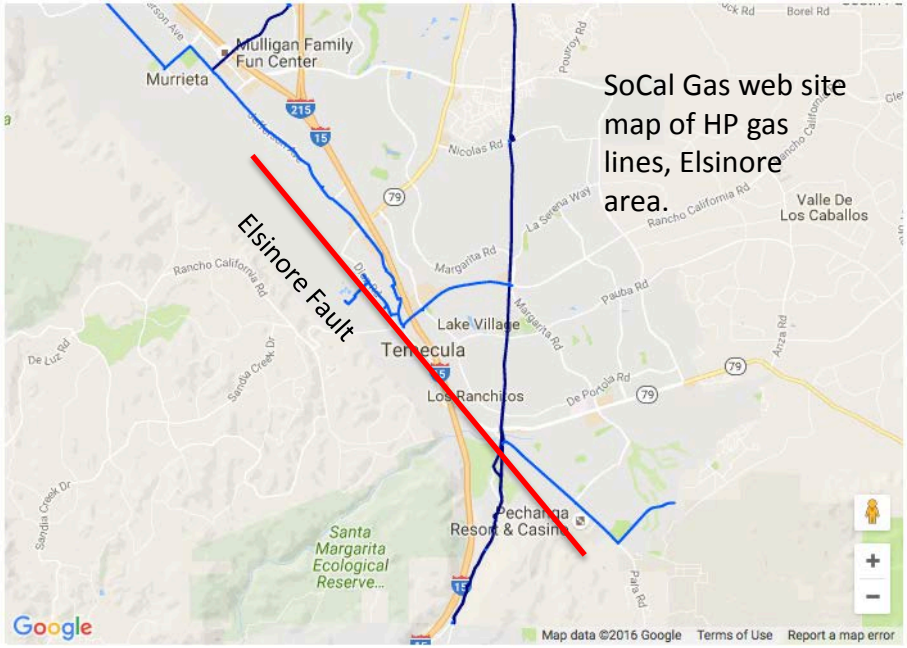


Example, High Pressure Gas Crossing, Elsinore Fault



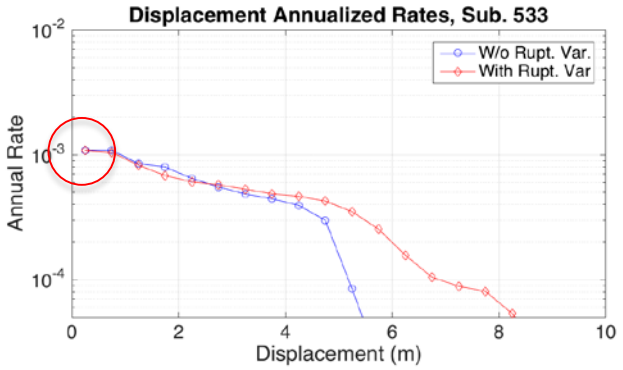


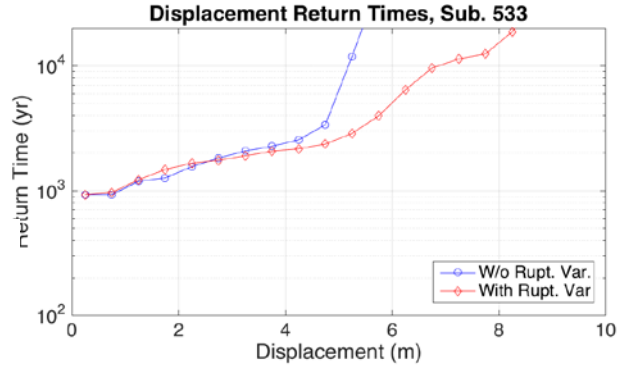
Example, High Pressure Gas Crossing, Elsinore Fault



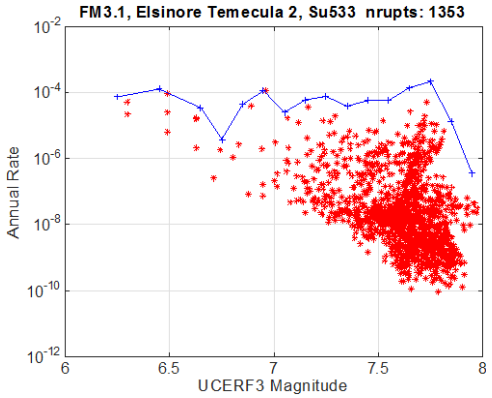
SoCal Gas web site map of HP gas lines, Elsinore area.

UCERF3 displacement annualized rate (upper right) and displacement return time (lower right)

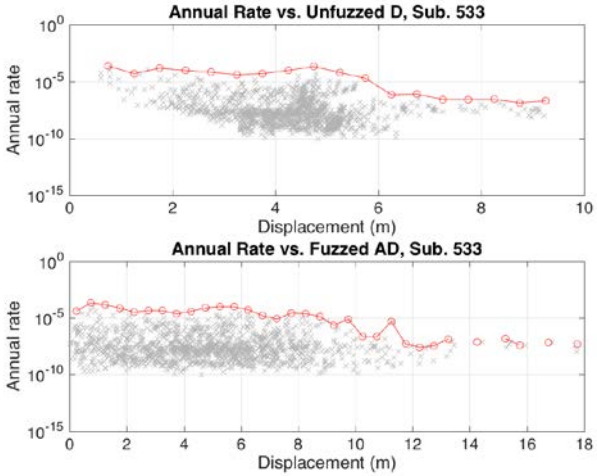




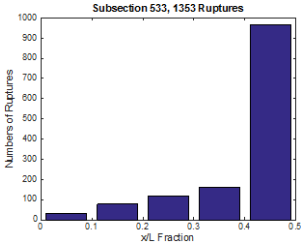
Red circle: annual rate that some displacement will occur (~1.1e-3/year)



Magnitude vs. frequency

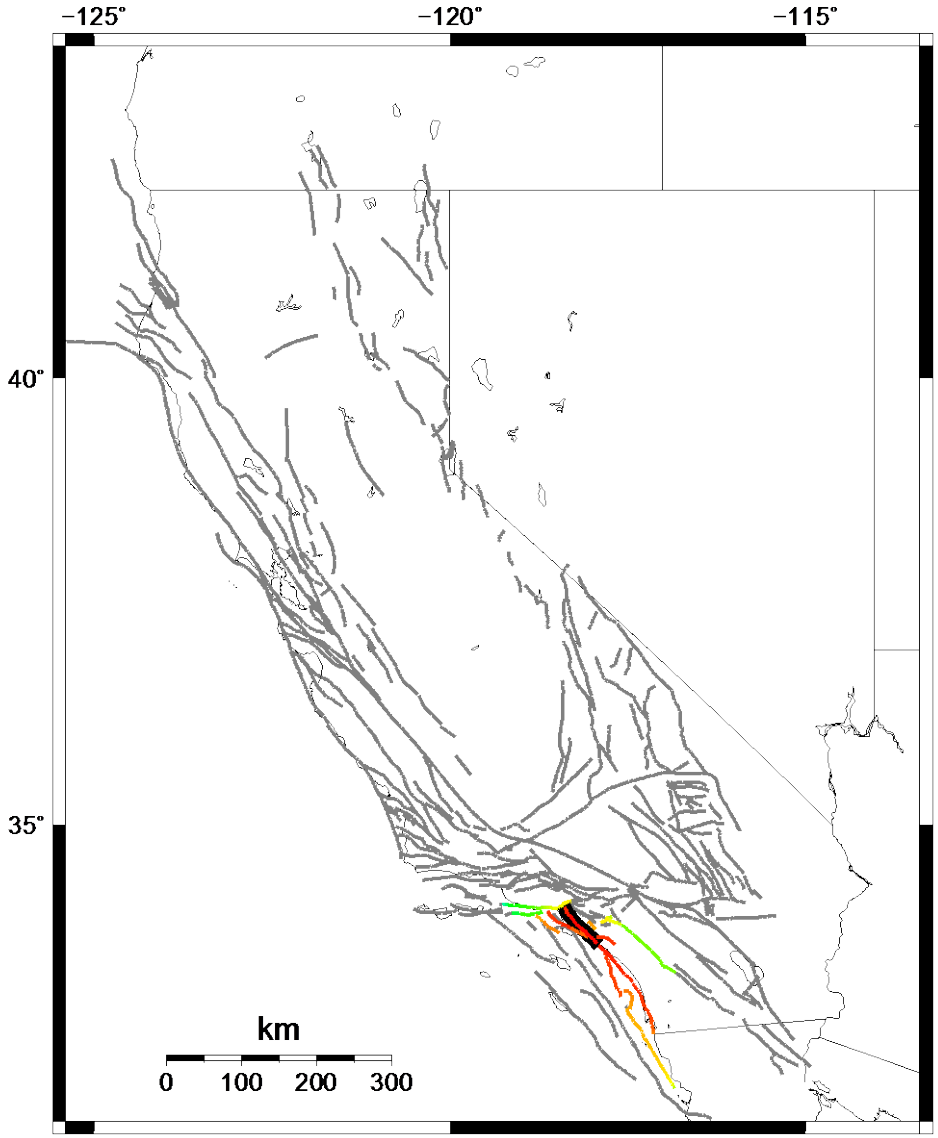


Displacement vs. frequency

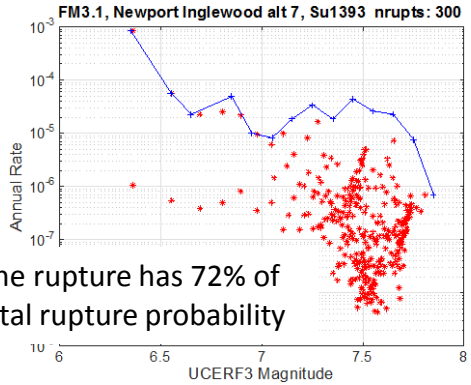


x in L distribution

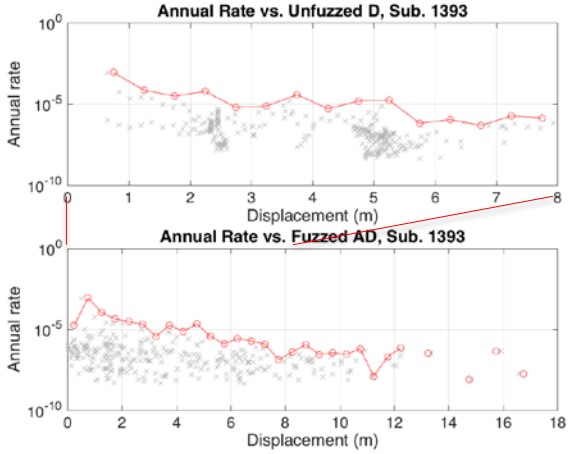
Newport Inglewood Fault Near LAX

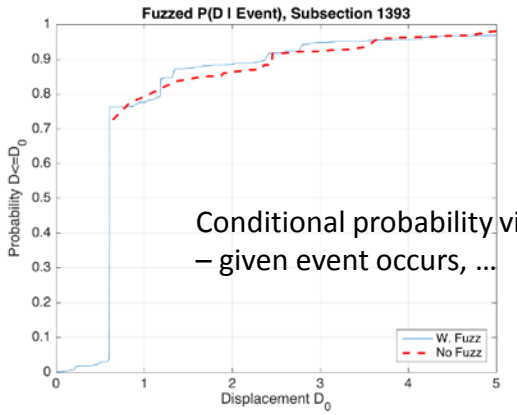


Newport Inglewood Fault Pipeline Crossing Near LAX



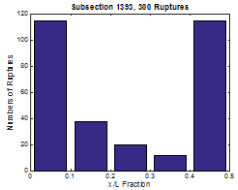
One rupture has 72% of total rupture probability



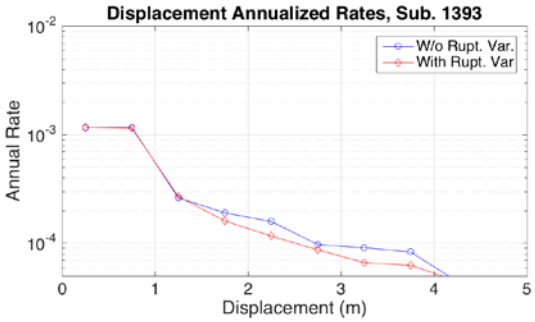


Conditional probability view – given event occurs, …

Magnitude-frequency
Site crossed by 300 UCERF3 ruptures.

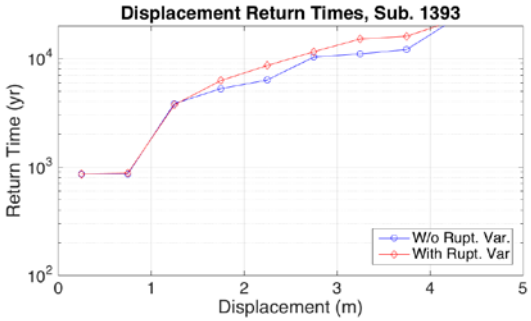


x in L distribution



Annual rates

Return times



Performance-Based PFDHA Using UCERF3: Conclusions

- UCERF3 provides many PFDHA components
  - Rupture set, length, magnitude, rupture end points
  - Probabilities of each rupture
  - Mean rupture displacements
  - In this sense UCERF3 is easier to use than UCERF2 or earlier forecasts.
- Displacement variability depends on normalized location (x/L) and rupture length
- Well-posed probabilistic fault displacement estimates can be developed for crossings of UCERF3 faults
  - Conditional probability given rupture
  - Actual probability: Return periods and annual rates of displacement