Operational earthquake forecasting during the M6.4 Searles Valley and M7.1 Ridgecrest sequence using the UCERF3-ETAS model—evaluation and lessons learned

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Background

By 11:07 am on July 4, 2019 (33 minutes after the M6.4 Searles Valley earthquake), the first UCERF3-ETAS aftershock simulations were running at the University of Southern California’s High-Performance Computing Center. UCERF3-ETAS (Field et al., 2017), an extension to the Third Uniform California Earthquake Rupture Forecast, is the first comprehensive fault-based epidemic-type aftershock sequence model. It produces ensemble simulations of aftershock sequences both on and between explicitly modeled UCERF3 faults to answer a key question in earthquake forecasting: What are the chances that an earthquake that just occurred will turn out to be the foreshock of an even bigger event? Standard short-term forecasting models in current use by the USGS and CEPEC do not explicitly consider the proximity of seismic activity to major faults like the Garlock.

Development of the UCERF3-ETAS code base during the past year allowed us to rapidly prepare Ridgecrest simulations. Moreover, new tools were quickly developed in the weeks following the M7.1 event, including the incorporation of 3-D finite rupture models, which allowed us to account explicitly for the distance between the observed rupture surfaces and neighboring faults. As various finite fault models were generated, sensitivity to rupture geometry became apparent, though the differences between all of the finite sources are much smaller than the difference between using our best finite source and point source. This suggests that, while sensitivities exist, inclusion of an uncertain finite source is still preferred over a point source model.

M7.1 Preferred Model Results (Finite Source)

A detailed finite rupture geometry was posted ComCat on Thursday, July 11, at 6:32 pm. This geometry was developed through analysis of coseismic deformation from INSAR. We developed the capability to scrape these sources for use in UCERF3-ETAS simulations on Tuesday, July 16, and have used that rupture geometry as our preferred model since.

Model Sensitivities

Sensitivity of various probabilities (bar charts) to different UCERF3-ETAS configurations. Simulation input fault geometry is shown on the bottom map view panels, with the M7.1 surface in gold. Probabilities are in the top chart panels, with the preferred model (ShakeMap finite source, default parameters) annotated with a black line.

Model Results (Finite Source)

UCERF3-ETAS provides useful information about fault probabilities after Ridgecrest, but can be sensitive to inputs

- Assesses probability of Ridgecrest triggering neighboring faults (e.g. Garlock)
- Such probabilities are sensitive to poorly constrained rupture geometry
- Still better to include a poorly constrained rupture surface than completely ignore finite fault extents (if interested in fault probabilities)

Having both (Ridgecrest was extremely valuable for learning about these sensitivities and motivating development of tools to improve response to future events

Timeline

Thursday, July 4, 2019

• 10:33 am: M6.4 Searles Valley occurred
• 11:07 am: First UCERF3-ETAS simulations running at USC HPC (point sources)

Friday, July 5, 2019

• 11:39 am: Initial results posted to response.scec.org
• 3% change of M6.4 in first week

Friday, July 5, 2019

• 4:02 pm: All 100k simulations finished, results updated

Friday, July 5, 2019

• 5:19 pm: M7.1 Ridgecrest occurred (initial reported M6.9)
• 8:11 pm: M6.6 point source simulations running at USC HPC (Kevin unavailable, submitted by Bill Savran)

Saturday, July 6, 2019

• 4:25 am: Point source simulations resubmitted with updated M7.1
• 9:38 am: Point source model M7.1 simulations completed
  ○ 1% chance of another M7.1 in first week
  ○ 0.46% chance of M7 on Garlock
• 10:30 am: CEPEC convenes, considers M7.1 results
  ○ 12:24 pm: UCERF3-ETAS input files and code modified to support arbitrary finite fault surfaces (not on UCERF3 faults)
  ○ 9:12 pm: First finite fault simulations submitted with extents drawn by Ned Field from aftershock sequence
    ○ 1.92% chance of another M7.1 in first week
    ○ 1.71% chance of M7 on Garlock

Tuesday, July 9, 2019

• 1:13 pm: ShakeMap planar finite fault source available (V10), based on teleseismic inversion
• 1:56 pm: UCERF3-ETAS tool developed to fetch events directly from ComCat to configure simulations, specify planar finite fault by strike, dip & length/depth extents
• 5:20 pm: Finite fault simulations with better hand drawn planar source complete
  ○ 3.95% chance of another M7.1 in first week
  ○ 4.93% chance of M7 on Garlock
• 6:32 pm: ShakeMap detailed finite fault source available (V14), based on INSAR

Tuesday, July 16, 2019

• 3:35 pm: UCERF3-ETAS tool updated to fetch complex ShakeMap finite sources from ComCat
• 8:10 pm: Finite fault simulations with complex ShakeMap source (V14) completed
  ○ 2.99% chance of another M7.1 in first week
  ○ 3.11% chance of M7 on Garlock
• 8:42 pm: ShakeMap finite fault source available (V15), based on teleseismic inversion

Thursday, July 11, 2019

• 1:56 pm: UCERF3-ETAS tool developed to fetch events directly from ComCat to configure simulations, specify planar finite fault by strike, dip & length/depth extents
• 5:20 pm: Finite fault simulations with better hand drawn planar source complete
  ○ 3.95% chance of another M7.1 in first week
  ○ 4.93% chance of M7 on Garlock
• 6:32 pm: ShakeMap detailed finite fault source available (V14), based on INSAR

Tuesday, July 16, 2019

• 3:35 pm: UCERF3-ETAS tool updated to fetch complex ShakeMap finite sources from ComCat

Friday, July 19, 2019

• 12:01 am: Finite fault simulations with complex ShakeMap source (V14) completed
  ○ 2.99% chance of another M7.1 in first week
  ○ 3.11% chance of M7 on Garlock

Questions?

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